TM 1–445

WAR DEPARTMENT

U. S. Dept. of Army

TECHNICAL MANUAL

INSTRUMENT FLYING TRAINING

June 18, 1942

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TECHNICAL MANUAL

INSTRUMENT FLYING TRAINING

CHANGES No. 1 | WAR DEPARTMENT, WASHINGTON, October 10, 1942.

TM 1–445, June 18, 1942, is changed as follows:

37. Setting the altimeter.—*a.* There are three types * * * obstacle clearance, instrument landings.

* * * * * * *

(2) *Obstacle clearance.*—In clearing an obstacle, * * * temperature at the plane. As an example, assume that the PA is 10,000 feet, outside temperature is −40° C., the actual altitude is approximately 8,670 feet, showing that the plane is 1,300 feet too low if a level of 10,000 feet is to be maintained. Climb the plane * * * altitude for clearance.

[A. G. 062.11 (10–3–42).] (C 1, Oct. 10, 1942.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

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TECHNICAL MANUAL

INSTRUMENT FLYING TRAINING

IANGES No. 2

WAR DEPARTMENT,
WASHINGTON, November 2, 1942.

TM 1–445, June 18, 1942, is changed as follows:

81. 90° system.

* * * * * * *

b. How it is done.

* * * * * * *

(4) After the beam * * * illustrated in figure 35. A simple ıle to remember is that when the maneuver leads from "like to like" from an A back into an A, or N back into an N) turn left 180°. **If, ı the other hand, the maneuver leads from "like to unlike" from an A into an N, or from an N into an A) turn left 270°.** : should be noted * * * crossing over the station.

(5) When the identifying turn * * * likely to become con ısed. When going from "like to **unlike**" the 270° turn should be :arted as soon as identification of the leg is definite. The sooner this ırn * * * as previously described.

* * * * * * *

[A. G. 062.11 (10–26–42).] (C 2, Nov. 2, 1942.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
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TECHNICAL MANUAL No. 1-445 }

WAR DEPARTMENT,
WASHINGTON, June 18, 1942.

INSTRUMENT FLYING TRAINING

*This manual supersedes TM 1-445, September 7, 1940.

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PART ONE

INSTRUCTORS' GUIDE

CHAPTER 1

GENERAL

1. Purpose and design.—The purpose of part one of this manual is to provide an instructors' guide for instrument flying training.

a. In the past it seemed expedient to design an instrument flying text around a set of maneuvers, i. e., the student first had to learn straight and level flying, then turns, then climbs and glides, etc.

b. This instructors' guide has been carefully designed around the instruments themselves in such a manner that the student will have no opportunity to acquire bad habits. *Each instrument is taken up in its proper order of importance.* If the order of the exercises is adhered to strictly, the various maneuvers dovetail perfectly at the proper time. The student's mental process will be correct, since at no time previously has he had an opportunity to fly incorrectly. The time spent in breaking bad habits is extremely costly to the training program. Bad habits acquired even temporarily are also hazardous to the student's future career by being a source of mental confusion under conditions of strain and mental pressure. The object of the instrument flying course, as outlined, is to give the student a sound knowledge of instrument flying and to enable him to meet the requirements prescribed in AAF Regulation 50–3 upon completion of the course. Stress has been placed upon outlining a definite procedure to be followed by the instructor. The outline is brief and the instructor must supplement it by using part two of this manual whenever applicable.

c. The instructor should press his students to perform each exercise and to concentrate on all the instruments concerned to the best of the student's ability. Even if the student does well, keep pushing him. Do not let him feel that you are entirely satisfied with any performance. This does not preclude occasional compliments on a particularly good effort or performance by the student.

d. As described herein, basic and advanced instrument flying constitute two distinct phases of instrument flying. Radio and navigation work should never be attempted until the pilot is proficient in all phases of the basic work. The advanced course develops skill in the

use of radio facilities and in navigation by dead reckoning, while on instrument, and teaches a pilot to conduct the course of his flight mission intelligently.

e. Definite limits of error are set up in order to standardize instruction. The student must be competent to execute a maneuver correctly before proceeding to the next one. A progress record of each student is to be kept and will go with him as he progresses through the training course. Thus, his instructors will be posted as to his proficiency. Any deviations from a proficiency basis will result only in confusion in the more advanced phases of training.

CHAPTER 2

BASIC INSTRUMENT FLYING

SECTION I

GENERAL INSTRUCTIONS

2. Order of instruments.—It will be noted that the exercises are so designed as to place the emphasis on the instruments in the following order:

a. The needle on turn and bank indicator.
b. The ball of the turn and bank indicator.
c. The air speed indicator.
d. Altimeter.
e. Clock.
f. Compass.
g. Vertical speed indicator.

3. Precautions.—In order to obtain the best results, the instructor, before starting instrument instruction, must make sure that the student understands the 1-2-3 system and the absolute necessity for following it. It should be pointed out to the student that he must be concerned only with the instruments that are brought to his attention by the instructor and that these instruments are taken up in their relative order of importance. The lack of dependability of the rate of climb (or vertical speed indicator) in rough air should be brought out and the student must be impressed with the necessity for always maintaining a constant check on his air speed indicator, particularly in turbulent air.

4. Instrument and control relationship.—There are several things that are of the utmost importance in teaching instrument training in general, which must be thoroughly impressed upon the student in the very beginning so he will never deviate from using them whenever he is on instruments:

a. Control the needle with the rudder.

b. Control the ball with the ailerons.

c. Control the air speed with the elevators.

d. Control the vertical speed with the throttle.

5. Time and proficiency.—During all phases of this course the turn indicator (gyro) and the flight indicator must be caged. The exercises should be given exactly as outlined in order to place the emphasis upon the proper instrument. The numbers of the exercises do not refer to the time to be devoted to them. It will be found that certain exercises will require more time than others. The minimum proficiency should be attained before going to the next step. The minimum proficiency, as set up under most of the exercises, is not necessarily the one to be finally attained. Constant repetition of the various maneuvers will be found necessary before the student can be considered thoroughly grounded in basic instrument flying.

6. Control.—By referring to the basic outline of exercises under the hood the following points will be noted:

a. Only one instrument is added at a time.

b. The instruments are taken up in their proper order of importance.

c. The student is not worried about maintaining an altitude until he has had training on the paper instrument (the air speed indicator) with which he maintains altitude eventually.

d. A normal turn (turn and bank indicator) of no specified amount is taught before he is worried about altitude or compass headings.

e. The student is proficient in throttle coordination before he has to struggle with given amounts of time or compass headings.

f. The joker of the instrument panel (the vertical speed indicator) is left until the last and is used for measuring vertical speed only when altitude is to be gained or lost.

TABLE I.—*Outline for basic instrument flying course*
(instruments register rate and amount)

	Refer to par.
1. Straight flight (turn and bank indicator only), + or — 15°	7
2. Straight climbs and glides (add air speed indicator); air speed + or — 5 mph, course + or — 10°	8
a. Various air speeds at cruising throttle.	
b. Various air speeds at other than cruising throttle.	
3. Climbs and glides with turns (standard rate) (no specified amount or headings). Air speed + or — 5 mph	9
4. Straight and level flight (add altimeter); air speed + or — 3 mph. Altitude + or — 100 feet	10
a. Find cruising air speed at various throttle settings.	
b. Change from one air speed to another with changing altitude.	

SECTION II

DESCRIPTION OF EXERCISES

(Cage gyros until attitude flying is taken up)

7. Straight flight.—*a.* Although the turn and bank indicator and the air speed may be taken up together with regards to how they are controlled, the instructor should assist the student at first by keeping the air speed reasonably constant in order that the student can concentrate on the turn and bank indicator. The turn and bank indicator should be thoroughly explained to the student. He should be impressed with the fact that while the ball is affected by gravity and centrifugal force, the needle is a gyro instrument and that every movement of the needle indicates that a turn has been made. Up until the student is ready for spins, he should be impressed not so much with the fact that he must center the needle for a straight course, but that he should compensate the needle. Any time the needle flicks to one side on a straight course, it must be moved over for an equal amount of time on the other side before the ship returns to its

original course. The same applies on holding a given rate of turn. Psychologically this assists the student's progress by giving him a means of correcting an error rather than leaving it to accumulate with others.

b. Relaxation is highly important in teaching instrument flying. It is much easier to compensate the needle with rudder pressure than it is to sit, stare at, and fight the needle with physical, mental, and nervous energy to prevent it from flickering at all. Under rough instrument conditions it is physically impossible to hold the turn needle still, so begin right at the beginning to inculcate good habits into the student.

c. Impress upon the student that instrument flying is a smooth proposition. His instruments are controlled to best advantage by a certain amount of pressure on the controls and not by arbitrary movements of them, disregarding pressure. Only in this manner will a student develop a "feel" of the controls in direct relation to his instruments.

d. Mentally the student must fly an instrument panel, not an airplane, nor the seat of his pants.

8. Climbs and glides.—*a.* The student should be taught at first to hold air speeds from a reasonably fast gliding speed to at least 20 mph above normal cruising with the throttle set for normal cruising. Instruct him to make maximum use of his stabilizer. There is no point in proceeding any further until the student can master the air speed to within a plus or minus 5 mph of the designated speed. Much can be done at this stage of the training by reminders over the interphone in a helpful tone of voice when it appears the student has momentarily neglected either the needle, bubble, or air speed indicator. This is the beginning of a systematic cultivation of a "roving eye" in the student which is vitally necessary in order to make an accomplished instrument pilot.

b. Repeat this exercise at other than cruising throttle settings (within the limits of the power applied).

c. The student should be impressed with the fact that the air speed indicator is a "history" instrument. The information it gives is something that has happened but not what is happening now. Consequently it is necessary to lead or anticipate the instrument slightly. If this instrument is controlled strictly by pressure on the stick with a very light-fingered touch, there will be no tendency to overcontrol. The reading on the air speed should be changed slowly, evenly, and steadily. Since the instrument lags, any noticeable acceleration of the rate of change in air speed is usually noticed too late to stop the indicator

on the desired air speed. Overcontrolling has already resulted. Careful control of the rate of change of air speed by slight back pressure on the stick will prevent excessive rate of change and will prevent overcontrol. An extremely light touch with the stick held lightly by the fingertips is the prevention for 90 percent of overcontrolling. During this exercise, at first, the instructor should set the throttle; later, as the student's ability increases, the student should take over its operation.

d. When the student can hold an air speed within + or − 5 mph and a course + or − 10°, the next exercises may be taken up.

9. Climbs and glides with turns.—*a*. As soon as air speed has been mastered, introduce the student to a one-needle-width turn while he practices the air speed exercise. Make no reference to a level turn or holding the altitude. Thus he becomes acquainted with a normal turn with no immediate additional worry. Stress here, again, compensating the needle in turns as was done to hold the airplane on a straight course. Do not allow the student to exceed standard rate turns during this exercise.

b. Explain to the student why the ball should be kept centered or slightly on the high side in a turn.

c. Proficiency, again, is ability to hold air speed within + or − 5 mph.

10. Straight and level flying.—*a*. During this phase the use of the altimeter is added. This highly important instrument should be thoroughly understood by every pilot. It will be dealt with thoroughly in a later section of this manual as its critical aspects are concerned directly with more advanced training. The altimeter is also a "history" instrument; its lag varies directly as the rate of change of altitude. If the rate of change of altitude is very small the lag is negligible, while with a fast rate of change of altitude the lag may be appreciable.

b. In this phase the student learns to control the altimeter with the throttle. Given an air speed and an altitude by the instructor, he should adjust the air speed with the elevators, then adjust the throttle until the altitude is maintained. Numerous variations of this exercise are possible within a range of one or two hundred feet. One important variation—the instructor should set the throttle and the student should find the cruising air speed which will maintain the altitude. This is highly important when it is desired to cruise at a given engine power output.

c. In rough air altitude will vary constantly and the student should be taught to return gradually to desired altitude by varying the air

speed with the elevators. This correction should not exceed 5 mph above or below cruising.

d. For every air speed correction there are three separate and distinct movements:

Making the correction.
Checking the controls.
Neutralizing the controls.

This order applies when returning to cruising after the air speed has been either decreased or increased. The inertia of the plane causes the air speed to lag when increasing the air speed just as the momentum of the plane causes the air speed to lag when attempting to decrease the air speed. When correcting for a loss in air speed, increase the forward pressure on the stick until the air speed stops decreasing and begins to increase. At this point the plane is in level flying attitude. A slight back pressure applied before neutralizing the controls is necessary to avoid overcontrolling into a diving attitude. It will take a few moments for the air speed to build up to cruising. Also in a dive, when the plane has returned to level attitude, a certain amount of momentum will remain as a result of the dive causing the air speed to read in excess of cruising even though the plane is on an even keel. (An inexperienced pilot will continue to pull back on the stick trying to reduce the excessive air speed, thinking he is still in a dive.) When an airplane is pulled out of a dive the air speed will remain at the terminal velocity of the dive until the plane is level. The air speed needle will then begin to move forward to cruising air speed. In checking a dive the pilot can detect when the plane is in level flight by noticing the instant that the air speed stops increasing and begins to decrease; the controls should be neutralized and a light forward pressure applied to avoid a climb as a result of the diving momentum. When the controls are neutralized, cross-check carefully against the altimeter to avoid changing attitude until the air speed reaches cruising. This may take several seconds.

e. At this point better control of the air speed indicator is expected. When the student can maintain air speed + or − 3 mph and altitude + or − 100 feet he may take up level turns.

NOTE.—No reference is to be made to rate of climb indicator. If it appears that the student is referring to it, it should be covered up.

11. Level turns.—*a.* Now that the student has learned the correct procedure for maintaining altitude, the instructor can concentrate on turns, beginning with one and two needle width turns.

(1) It is necessary here to point out to the student that in a turn of any sort he is reducing the vertical component of lift in the wings which will also cause a loss in altitude. This vertical component can be increased by holding the nose of the plane slightly higher (increasing the angle of attack). But if the nose is raised, the air speed will decrease. Consequently, as a turn progresses or is increased it will be necessary to cruise the ship 2 or 3 mph less to maintain altitude than was necessary in straight and level flight.

(2) Precautionary measures should be taken to prevent so-called "turn tightening" by explaining thoroughly to the student exactly what happens and what causes it. Turn tightening results from the fact that students fail to realize (while under the hood) that certain controls exchange functions partially in a turn. The steeper the turn, the more these functions are exchanged. In a very steep turn the elevators assume to a great extent the function of the rudder in keeping the turn needle constant and the rudder assumes the function of the elevators in keeping the air speed (which controls altitude) constant. Not realizing this fact, the student starts a turn and the nose drops, increasing the air speed and decreasing the altitude. Reefing back on the stick to decrease air speed and increase altitude merely tightens the turn, which drops the nose again, giving another increase in air speed and decrease in altitude. A vicious circle exists, resulting in a tight spiral and eventually a power-on spin.

(3) In learning to do steep turns, if the instructor insists on the student going into the turn slowly and steadily, keeping all the instruments under control, no great difficulty should be encountered. Stop the maneuver when the control begins to be erratic and begin all over. If a spiral has resulted, recover straight and level flight with the turn and bank indicator and air speed and go into a consultation.

b. Before beginning time turns, check the turn and bank indicator against the clock with the hood open to determine its condition of adjustment. If it is not indicating a 3 degree/second turn, warn the student how to compensate for this by turning a certain number of seconds more or less than normal. Dividing mentally the number of degrees of turn required by 3 and interpolating for rate of turn error between the 90° quadrant will give very accurate results. For best results on time turns, begin the timing at the same instant that the plane starts rolling into the turn. Hold the full needle turn until the total time has expired and then roll out at the same rate that the plane was rolled into the turn.

c. In turning to headings of odd amounts, teach the student to divide these headings by 3 to get the time of turn. If the instructor says

"Turn left, 75°," have the student answer "Left, 25 seconds." If the student is flying east and the instructor says "Turn left, to a heading of 330°," have the student answer "Left, 40 seconds." Although students should be taught to turn by counting the seconds for any turn, the maximum value in counting time is for turns of less than 90°. It eliminates the use of an additional instrument, the clock, when small accurate changes are desired. This is particularly true when several small turns are desired in succession.

NOTE.—For further information on counting turns see paragraph 48c.

d. A word about the compass at this point. Students are often confused in the use of compass by the oscillation and kick-off. Since the kick-off is caused by the dip of the earth's magnetic field, it is apparent that the maximum kick-off is on north and south, and that no kick-off is apparent on east and west. On north and south the maximum kick-off in degrees is roughly equal to the latitude of the locality. When on north, the compass kicks off in the opposite direction of the turn and lags behind the actual heading until the ship heads either east or west. When the ship heads south, the kick-off is the same direction of the turn and leads the turn an ever decreasing amount until the ship heads east or west. Conversely, any acceleration or deceleration in an easterly or westerly direction will also give a kick-off but will have no effect flying north or south.

e. Knowing the action of a compass as described above, the student should be able to use better judgment in making small corrections for maintaining a course. He should never try to turn with the compass by trying to outguess it, but he should be less confused by its apparent aimless gyrations if he understands it.

f. The air speed indicator should be controlled at this point within 2 mph. The allowance of 5° per 90° turn is permissible.

12. Climbs and glides with given vertical speed.—*a.* The rate of climb indicator should be thoroughly explained. The confusion which results when the needle winds up past the 180° mark should be stressed. This instrument has the greatest lag of any instrument on the panel. So great is the lag after any large deflection of the needle in a dive, spin, or excessive climb, that the instant the needle starts to return toward zero the ship is already approximately in a level attitude, and back pressure should be applied to prevent overcontrolling. In any extreme maneuver or attitude, disregard the vertical speed and use only the air speed indicator.

b. The vertical speed indicator is properly used only in establishing a given rate of climb or descent and is controlled with the throttle only.

It is impossible to hold a given vertical speed unless the air speed is constant. No attempt should be made to adjust the vertical speed with the throttle until the correct air speed is being held first by use of the elevators. The student should first learn to control vertical speed without changing air speed. Teach him to "squeeze" the needle down with the throttle.

c. At first the student will find that it takes an appreciable length of time to set up an air speed and vertical speed by close coordination of throttle and elevator. He will soon find, as he becomes more familiar with his equipment, that a certain amount of power (rpm or mp) will give him the desired air speed and vertical speed. The short cut to setting up a glide, then, is to retard the throttle momentarily, easing back on the elevators to kill the air speed (being careful to guard against zooming). The instant that the altitude can hardly be held any longer and both the air speed and vertical speed indicators start to go down, push the throttle to the predetermined power output and stabilize the air speed at the given velocity with the elevators. A very slight trimming with the throttle may be necessary to set the exact rate of descent. Do not adjust the throttle unless the air speed is exactly right or the change will be wrong.

d. Climbs and glides should be practiced at various air speeds and vertical speed combinations but a let-down of 120 mph and 500 ft/min should be stressed as it is a very convenient figure for mental calculation; 120 mph is 2 miles per minute and at 500 ft/min it takes 2 minutes to change altitude 1,000 ft. This is an important factor in single place ships.

e. The loss of altitude effect is even more pronounced in a turn while gliding than it is in a level turn. This may be eliminated by adding a touch of throttle as the plane is rolled into the turn during a glide.

f. Since an airplane cannot be put into a given glide instantaneously, it must be explained to the student that to attain a given vertical speed such as 500 ft/min the needle must be kept a little lower (or higher) such as 550-600 ft/min, according to the promptness with which he set up the glide (climb). When a loss or gain of 1,000 feet is desired, the change in altitude can be cross-checked with the clock at the 500-foot mark and adjustment can be made to obtain the correct average amount.

g. The air speed indicator should be controlled within 2 mph, turns should not be in error more than 5° per 90° turn, and the vertical speed should be maintained within 100 ft/min average.

13. Stalls power on and power off.—*a.* The primary consideration in the execution of stalls is the ability to recover quickly

and surely with a minimum loss of altitude. This point should be emphasized in teaching this exercise as a precision maneuver. A high development of the "roving eye" is necessary to attain expert recovery, hence the student will be required to use all his ability to control the instruments.

b. The power on stall is the first to be executed and this is accomplished by simply decreasing the air speed from the cruising position until the airplane has lost flying speed (care must be observed to prevent excessive zooming by too rapid application of back stick pressure). Recovery is effected by immediate forward movement of the stick, keeping the needle centered, and returning to the desired air speed.

c. The power off stall is done in much the same manner except that the throttle is out and gradual back stick pressure is exerted to decrease the air speed, maintaining the altitude as long as possible (guarding against zooming again). The instant that flying speed has been lost open the throttle and return to cruising.

d. Proficiency should be gaged by the ability to recover quickly and surely without excessive diving.

14. Spins.—*a.* Again recovery is the primary consideration. Before attempting a spin recovery the student should be required to recover from a steep spiral. In this connection the student should be warned that he must adhere to the 1–2–3 system in effecting recovery, as further back pressure on the stick without first centering the needle and ball merely steepens the turn, tightens the spiral, and makes recovery more difficult.

b. To prevent faulty entry, the instructor should put the airplane in the spin. The student should recover on a prearranged signal from the instructor, following again the 1–2–3 system of recovery. The student should be forewarned against vertigo and cautioned to "fly the instruments." A general tendency of most students is to ignore the turn bank indicator after having once centered it, thus ending up in a tight, steep, spiral at excessively high air speeds.

c. Proficiency should be gaged by the student's ability to recover without approaching a second stall or a steep spiral.

15. Attitude flying.—*a. General.*—Attitude flying is the technique of instrument flying, making maximum use of the directional gyro and flight indicator in conjunction with the basic instruments. It is based on the fact that for a given amount of power, the attitude of the ship in relation to a plane parallel to the earth's surface determines the maneuver which results. It is almost impossible to maintain a constant attitude in an airplane under turbulent conditions without the gyro instruments. Only by intelligent use of these instruments

can anything approaching real precision flying be attained. The purpose of the directional gyro and the flight indicator is to establish fixed references for maintaining flight attitude. It will be necessary to know a little about how these instruments work to interpret properly their indications.

b. Directional gyro.—The directional gyro is a gyroscope rotating about a horizontal free axis. It is provided with an azimuth card and a setting device. This gyro works on a fundamental gyroscopic principle—rigidity. There is *no lag* in this instrument because the gyro remains fixed, and the case, which is attached to the airplane, rotates around the gyro.

(1) In holding a straight flight the gyro should be reset with the magnetic compass at least every 10 or 15 minutes to correct from the "creep." The average creep for a good instrument should be not more than 3° per 15 minutes on cardinal headings and not more than 5° per 15 minutes on any heading. Care must be taken in resetting the directional gyro that a constant heading, straight and level, is held until the magnetic compass steadies down or until the mean of the limits of swing can be determined.

(2) In general, the directional gyro cannot be used when the degree of pitch or bank is in excess of 55° because the mechanical stops within the instrument itself tend to upset the gyro. If these limits are exceeded, the gyro can always be caged and reset. For general use this instrument should be lined up with the magnetic compass, and reset when it has precessed 5°.

c. Flight indicator.—The flight indicator should be read by the pilot in the same manner that the natural horizon is observed. If the pilot imagines that he is sitting in the little airplane and maneuvering it in relation to the horizon beyond, it is very natural to read the instrument. The reactions to it are the same as when on contact.

(1) It should be remembered again that there is no lag to this instrument. The gyro rotates in a horizontal plane around a vertical axis. In normal operation its axis stays vertical. If it is tipped from the vertical, a certain mechanism within the instrument slowly rights it again. This action is apparent to the pilot in a simple turn which shows itself in the following manner. If a turn of 180° is made and the ship leveled off, it will be noticed that the little airplane is not quite parallel to the horizon bar. A few seconds of straight flight give the mechanism which rights the vertical axis time to operate and the horizon is again parallel to the earth. This lag is not more than 2° or 3°. However, after passing the 180° mark, if the turn is continued, this error tends to cancel out completely at the 360° mark.

This shows that the error is not cumulative and that the instrument can be depended upon for any given amount of turn. The error at the 180° mark is hardly noticeable but is mentioned here so that if it is noticed it will not be taken as an indication that the instrument is not operating properly.

(2) The operating limits of the flight indicator are determined by the mechanical stops within the instrument. This instrument should not be used in climbs or glides greater than 70° or in banks greater than vertical banks. If turns of more than 55° banks are to be made, the directional gyro should be caged but the flight indicator can still be used up to vertical banks.

(3) It will be found that if careful attention is paid to the proper nose high position that is observed when going into and holding a turn on contact, and this is then translated to the flight indicator on instruments, very accurate results can be obtained.

(4) It should be remembered that this instrument shows only the attitudes of the ship with relation to the ground and does not necessarily indicate a climb or a glide. For each different power output of the motor, the airplane will have a slightly different attitude with respect to the ground. When the straight and level attitude has been found for any particular power output, the little airplane on the flight indicator should be adjusted up or down with the adjusting knob until it lines up with the horizon bar. The instrument now indicates a nose up or nose down attitude directly.

(5) Care should be taken when originally uncaging this instrument to have the plane in a straight and level attitude, otherwise the instrument will be in error for a few minutes until the righting mechanism has had time to process the gyro to a vertical position. If the gyro has once been upset in the old type flight indicator, it may take as much as 15 minutes for the righting mechanism to be effective. The new type which is now installed in most planes can be caged and set immediately.

(6) Both the directional gyro and the flight indicator gyro turn up between 10,000 and 12,000 rpm. If the gyros are not turning fast enough, the instruments are not dependable. It takes at least 3 inches of vacuum about 5 minutes to get these instruments turning up. They should operate between 3½ and 4 inches satisfactorily but much better results are obtained with at least 3.7 inches of vacuum. Any more vacuum up to 4½ inches is satisfactory. Always check the vacuum gage; if it reads low it can sometimes be increased by switching to the alternate source which is a venturi tube. In some ships there is a switch which will divert all the vacuum to either the

front or rear cockpit. Using this switch will often bring up the vacuum in one position when it will not handle both positions together.

(7) Very accurate turns can be made by the gyro instrument by holding a given amount of bank and "nose up" position with the flight indicator, keeping the bubble of the turn indicator centered with the rudders.

(8) These instruments should be continually cross-checked against the basic instruments. To prevent damage to instruments, cage both before engaging in acrobatics. The advantages of using the gyro instruments are—

(*a*) Relieving excess pilot fatigue in prolonged instrument flights.

(*b*) Permit execution of precision maneuvers by giving the pilot a means of precisely controlling the attitude of the ship to a degree that is almost impossible with the other instruments.

(*c*) To facilitate rough air flying. The gyros are not affected by rough, turbulent air and their indications do not "jitter" and "bobble" around as will happen on the other instruments.

(*d*) Their reading is natural to the pilot and does not have to be interpreted from a dial.

d. Erratic indications and remedies.—A gyro-horizon or directional gyro, if properly installed, should not require overhaul in less than three or four hundred hours and should not require attention other than replacement of the filter during this period. Any trouble encountered probably will be due to a clogged filter, excessive vibration, or improper vacuum supply. For the latter reason a vacuum gage is installed with the gyro-horizon and directional gyro to enable the user to determine at any time whether or not the instrument is operating under proper vacuum. The following troubles and causes will assist in determining the cause of any malfunctioning of the gyro-horizon or directional gyro. (Tests (1), (2), and (3) to be made at cruising speed, cruising rpm, and in level flight.)

(1) *Bar fails to respond.*—Causes:

(*a*) No vacuum.

(*b*) Air filter disk dirty, reducing air flow.

(*c*) Leaks in instrument case.

(2) *Bar does not settle level.*—Causes:

(*a*) Excessive vibration.

(*b*) Low vacuum.

(*c*) Air filter disk dirty, reducing air flow.

(3) *Bar oscillates or shimmies.*—Causes:

(*a*) Excessive vibration.

(*b*) Vacuum too high.

(4) *Dial spins continuously in one direction or drifts excessively in either direction.*—Causes:

(*a*) Excessive vibration.

(*b*) Incorrect vacuum.

(*c*) Air filter disk dirty, reducing air flow.

NOTE.—The gyro-horizon and the directional gyro should be operated on a vacuum supply of 3.7 to 4 inches of mercury. The rotor speed is approximately 12,000 rpm.

(5) If the vacuum is found to be correct and vibration not excessive, and the trouble still exists, the cause is probably due to worn pivots or bearings. In such a case the instrument should be removed from the airplane for inspection in accordance with the instructions.

SECTION III

SUGGESTIONS FOR INSTRUCTOR, BASIC COURSE

16. Suggestions.—*a.* There are a few suggestions for the instructor to observe when introducing a student to instrument flying to obtain best results. The instructor should explain the maneuvers prior to take-off and point out to the student the correct position of the instrument readings for the different maneuvers. The student should be cautioned to use pressure on the controls instead of movement, in order to prevent jerkiness and overcontrolling. In the beginning of the course, the instructor should adjust the stabilizer and later the student should be taught to use the elevators to set the air-speed before adjusting the stabilizer to remove pressure on the stick. The instructor should be alert to recognize fatigue, especially in the beginning. Instrument flying induces fatigue much quicker than an equal period of contact flying. Long periods of instruction should be avoided. Short periods of rest should be given the student during the flight period to enable him to relax when under the hood. This usually can be accomplished satisfactorily if the instructor will take the controls for a few minutes while he is explaining a new exercise or correcting an old one. The instructor should avoid excessive corrections, especially when the student is attempting to execute a maneuver, as excessive correction leads only to further confusion. One mistake should be taken up at a time.

b. The student should be given exact instruction with regard to going under the hood and taking over the controls. At a prearranged altitude the instructor should tell the student to go under the hood.

The student should be allowed a few moments to become oriented and to direct his attention to the instrument panel while the instructor is still flying the airplane. Then he should be instructed to shake the stick when he is ready to take over the controls. After the student takes over the controls he must be allowed a certain "steadying down" period as he cannot close the hood and function immediately with maximum precision and efficiency, especially in the beginning. It is always best, therefore, when the student gets well along with his work for the instructor to give a few simple maneuvers before commencing the work of the period. It would be well to review everything previously covered in a sequence that puts the easiest and longest-practised exercises first in order to establish confidence and relaxation. After each exercise the student should be permitted a period of time to "steady down" again before the instructor either corrects the maneuver or gives instruction for the next one.

c. (1) Most students in basic instrument flying experience considerable difficulty when attempting to level off at a predetermined altitude from a climb in high rpm to level flight in low rpm. The tendency is to attempt to reach cruising speed too quickly, which results in a loss of altitude. (See par. 46*d* and *e*.) To correct this the student usually advances the throttle until it is at or near the wide-open position and then becomes further confused when the airplane begins to climb. The student should be instructed to climb steadily until the desired altitude is reached. At that point the propeller pitch should be changed, holding the air speed constant and then adjusting the throttle to the usual cruising position. The air speed should then be increased gradually, allowing the engine sufficient time to pick up rpm. The trend on the altimeter should then be noted; if a loss of altitude appears, the air speed should be held constant for a moment. The student should attempt, in this manner, to increase the air speed as much as possible without losing altitude excessively, until an air speed is reached which, if held, will cause a slow definite downward trend on the altimeter. This air speed, which causes a slow downward trend on the altimeter, will be 1 or 2 miles per hour higher than the air speed required to keep the airplane at a constant altitude for the particular throttle setting.

(2) If altitude has been gained or lost during the preceding process, it is a simple matter to regain the desired altitude by increasing or decreasing the air speed approximately 5 miles per hour for a few moments.

(3) Much the same problem is presented when attempting to level off from a glide. In executing this maneuver satisfactory results will

be obtained if the throttle is advanced approximately 50 feet from the desired altitude, holding the air speed constant until the rate of descent is checked and then proceeding in the same manner as in leveling off from a climb.

d. It is essential that instrument flying, as taught in the airplane and as taught in the instrument flying trainer (Link trainer), be coordinated if the student is to receive the maximum benefit from the instruction. It is highly desirable that instrument training begin on the Link trainer under trained instructors, so that the student has at least 2 hours of instruction in the Link trainer prior to his first instrument flight. In this manner valuable flying time can be saved and more complete training assured. It will be noted that in some instances the course prescribed in this guide deviates from that outlined in part two. This deviation is necessitated because of the differences between the airplane and the instrument flying trainer and is necessary to avoid a waste of flying time.

Chapter 3

ADVANCED INSTRUMENT FLYING

Table II.—*Outline for advanced instrument flying course*

	Refer to par.
1. Radio range flying	17
a. Intercepting and riding beam.	
(1) Beam bracketing.	
(2) Split system.	
b. Orientation.	
(1) True fade-out method.	
(2) Fade-out 90° method.	
(3) Special case procedure.	
(*a*) Lost on beam procedure.	
(*b*) Close in procedure.	
(4) Let-down and low approach.	
2. Radio compass, orientation, overhead, let-down	18–33
3. Altimeters	34–38

Section I

RADIO RANGE FLYING

17. Radio range flying.—*a.* Without going into detail on points which are in general well-known, a few observations on radio work follow which may prove useful to the instructor.

b. Learn to analyze the different methods of radio and orientation procedures which are advanced and evaluate them logically. Of the several recognized books on flying it will be found that one author favors one method and one favors another. A detailed and impartial description and analysis of the best-known radio beam procedures is to be found in paragraphs 71 to 91, inclusive. It would be well for every pilot as well as instructor to study those paragraphs thoroughly. The student should be thoroughly grounded in basic instruments and gyro instruments before being permitted to advance to radio work. He should have the radio range station and antenna systems explained to him thoroughly before flying the range so that he knows exactly what he is trying to do. This also is described in paragraphs 62 to 70,

inclusive. If the student understands exactly how radio signals are propagated he can interpret intelligently the sounds over the radio. Avoid being too brief and sketchy in giving the student all the information that he should have concerning instrument flying and radio procedure. Do not try to bluff. If you do not know the exact explanation on questions that are asked, look it up!

c. Reference only will be given as to details of the following maneuvers:

(1) *Intercepting and riding beams.*—(*a*) *Beam bracketing* (see par. 77).—Although any method of finding a beam heading is some form of bracketing, the term "beam bracketing," as far as the Army Air Forces is concerned, refers to the particular method of bracketing a beam *by sound* with a series of one-needle turns. The term "beam bracketing" is used for this method in contradistinction to the other method taught in the Army Air Forces, namely the "split system" which is a series of straight courses. Beam bracketing is by far the fastest and most reliable system yet devised for establishing the apparent heading of a radio beam. The mechanics of this system are unaffected by high winds and large amounts of drift, making it highly reliable where the other methods usually break down. The only disadvantage of this method has been that it required considerably more time to teach. This is not a fault of the system itself but rather that the student has not been well grounded in basic instrument flying. Offhand it appears that there is considerable mental calculation connected with beam bracketing, but on careful analysis it will be found that there are only two figures which need be remembered at any one time: the last heading which took the plane into the beam, and the last heading which took the plane off the beam. The more carefully the pilot's attention is directed to signal change, the faster the operation is accomplished. A very good execution should have the beam narrowed down to within 5° in about four turn reversals. The prerequisites for beam bracketing are proficient basic work and practice on the instrument flying trainer until the mechanics of the system are mastered. The right-hand edge of a beam is that point where the on-course is audible continually and the signal on the right of the beam can be heard very faintly (only every fourth or fifth signal) superimposed on the on-course. When the station is very near and the beam very narrow, the plane should be eased over into the solid on-course signal until the cone is reached.

(*b*) *Split system.*—The method of finding a beam heading by a series of straight courses is called the "split system" because the difference between the outgoing and incoming headings to a beam is

halved for the next heading. This system is relatively slow, and is easily affected by wind. It takes at least 5 minutes to set up the heading, which means that the plane has to be 10 miles or more from the station to begin the procedure. The mechanics of the split system are as follows: When the on-course signal is heard, turn to the published beam heading. When plane drifts off, correct 10° toward beam. When beam is reached, remove 5° of the correction and wait until ship again drifts off. On first off-course signal, correct 2° or 3° back toward beam. This system basically is not nearly as precise as beam bracketing, since in using the split system the beam area is bracketed, while in beam bracketing the right-hand edge of the beam is bracketed, which is a very definite line. If the first 10° correction is not sufficient to return the plane to the on-course in 1 minute, add another 10° correction.

(2) *Orientation.*—(*a*) The "true fade-out" method of orientation (see par. 82) is the most reliable method for all conditions. High winds do not affect the reliability of this system. For certain problems, with the wind direction and velocity fairly well known, as well as the station pattern and locality, some other system might be slightly more efficient, providing the pilot knows what he is doing and will not become confused. Students cannot be depended on to do this. The true fade-out method depends primarily on the pilot's ability to execute a good beam bracketing problem.

(*b*) The next best system is the "fade-out 90°" method (see par. 85). It takes a fairly bad wind condition plus a poor station pattern to confuse this method, providing accurate headings are flown with ships as fast as most military ships. (The slower the ship, the larger the drift angle for the same wind velocity.) In flying any method which depends on a 90° turn it should be remembered that after the quadrant has been determined by a fade or build on the average bisector heading, the course should be adjusted to the true bisector of that quadrant preparatory to making a 90° identifying turn. The so-called "Kelly Field" method is the fade-out 90° method with a 90° turn left instead of right. If the student is using beam bracketing to get on the beam, the right turn is more advantageous. If the student is using the "split system," the left turn is more advantageous because it puts him on the proper side of the beam so he can fly away from the station first, to allow time to obtain a bracket on the beam when heading back toward the station before he arrives over the cone of silence.

(*c*) The special cases of being "lost on the beam," etc., turning on radio and finding oneself on the on-course, and the "close in procedure"

are the easiest of all. The first case, "lost on beam," eliminates the necessity of proving a zone by getting a build or fade. The second case resolves itself down merely to picking the leg one desires to approach the station on and flying out the beam and turning around. Part two gives alternate methods of procedure for these special cases, each of which has the same limitation as the basic orientation method from which it is derived.

(*d*) Let-down and low approach procedure (par. 91) plus emergency pull-up (par. 55) speak for themselves as far as value goes. They go hand in hand and should be practiced together as a unit. Upon these two depends the final success of any instrument flight when an actual instrument landing cannot be made for lack of facilities.

SECTION II

RADIO COMPASS

18. General.—*a.* There are occasional situations when radio range orientation is inadequate due to excessive false fades, swinging beams, etc. There are also many occasions, especially in military flying, when radio beams are not available, such as over-water flight and cross-country flight which do not coincide with civil airways.

b. The radio compass or direction finder in such cases provides another means of obtaining a "fix" or position and also a means of "homing" directly to a given station.

(1) There is some confusion regarding the difference between a radio compass and a direction finder. For the purpose of this manual, the terms "radio compass" and "direction finder" (D/F) will be used interchangeably, depending on its functional use.

(2) All radio compasses utilize as a fundamental principle the fact that certain types of antennas are highly directional, and when the source of energy (radio transmitting station) bears certain angular relations to the plane of the antenna, the ratio of response (volume) of the received energy will be evident to the observer through a suitable indicating instrument. Different designs of radio compasses indicate this maximum or minimum by various methods, such as left-right indicator, neon light, "null" in earphones, minimum or maximum indications on a suitable meter, etc. These include the more commonly used left-right radio compass, homing devices, aural-null direction finders, etc. The antennas usually take the form of a loop which has maximum response when the plane of the loop is in line with the radio transmitting station (fig. 1) and minimum response when the axis of the loop is in line with station (fig. 2).

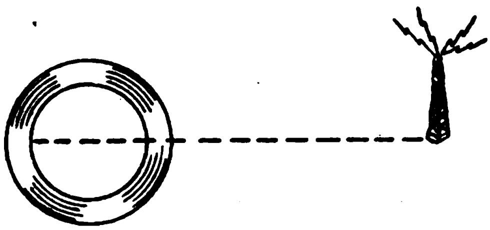


FIGURE 1.

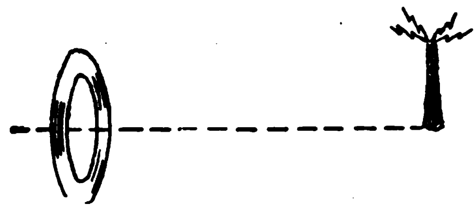


FIGURE 2.

(3) There are two types of radio compasses: those with a loop fixed to the airplane, and those with a rotatable loop which can be rotated and controlled from the cockpit. There are also two types of indications: visual, by means of a left-right indicator; and the aural-null method, in which the minimum signal is used as the reference.

19. Fixed loop radio compass.—*a.* After tuning in the desired station it is necessary to determine whether the station is in front or behind. With the visual indicator this is relatively simple. The needle may be centered with the station either in front or behind it, but if the station is behind, the indications of the needle will be reversed.

b. The indicating needle points toward the station; if the needle is to the right a right-hand turn is required to center it, and if it is to the left a left-hand turn is required to center it. To avoid loss of time, the pilot should turn toward the needle until the needle is centered. Homing with this device is then only a matter of keeping the radio compass needle centered. If there is a cross wind the track to the station will not, however, be in a straight line.

20. Fixed loop using aural null.—With this method the radio station is tuned in and a standard rate turn is started and continued

until a minimum signal strength is received. The volume control should be adjusted to give as narrow a null as possible. The station may then be either in front or behind. There are two methods of solving this ambiguity. If another station is available and can be tuned in, a line of position may be obtained from both stations and the resulting fix will determine the direction to the station. (This is called triangulation and will be taken up in detail later.) The other method is as follows: Note the bearing of the null, then turn 90° to the left and fly this heading for several minutes. Then turn to the right until the null is again found. If the bearing of the null is now less, the station is behind; if the bearing is greater, the station is in front. (See fig. 3.)

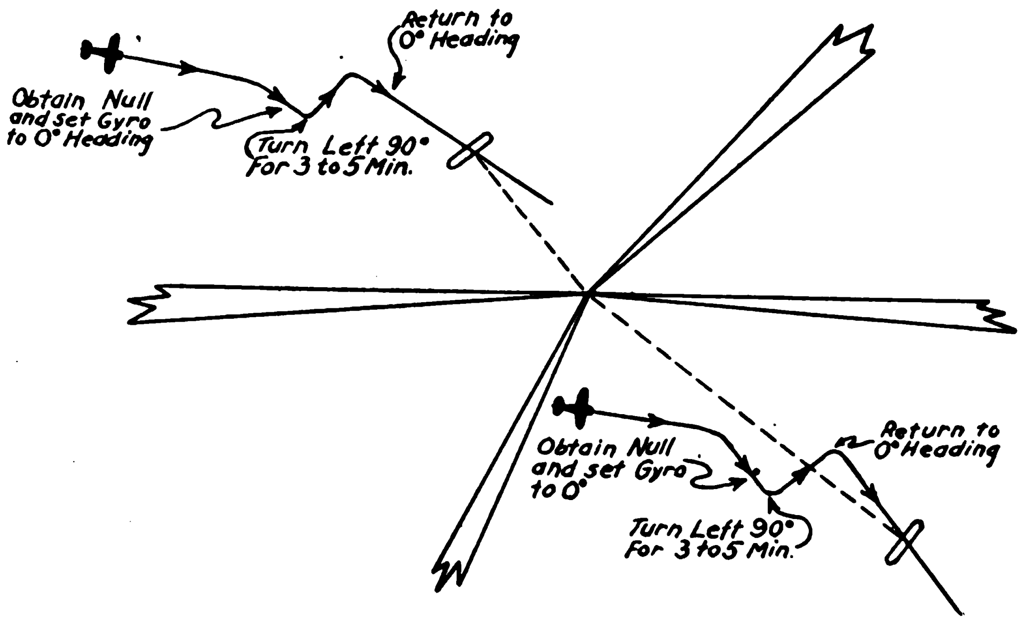


FIGURE 3.—Bearing using aural-null method.

21. Obtaining bearings.—*a.* In order to obtain bearings with these radio compasses it is necessary to use the maximum or minimum response indication as a reference to determine when the azimuth needle is in a correct position to be read. In practice this is accomplished by remote rotation of the loop until the indicating instrument shows the desired indication, and then observing the bearing as shown by a needle which is mechanically linked with the loop antenna and rotates across the face of an azimuth scale.

b. The angular bearing thus indicated is that of the radio station relative to the nose of the aircraft, and is equivalent to the bearings obtained by the navigator of a ship at sea using a pelorus and sighting on an object (such as a lighthouse) on shore. (See fig. 4.) The

bearings taken by the radio compass are in fact an extension of the visual method, utilizing radio waves instead of light waves as a medium for transmission.

c. By reference to figure 5 it will be seen that the bearing of 45° obtained by the radio compass is only relative to the nose of an airplane. If the ship in figure 4 or the airplane in figure 5 changes its course by as much as 1°, the angular bearing relative to the nose (or bow) will change in exact proportion. It will also be seen that as the ship or aircraft continues on its course the angular bearing relative to

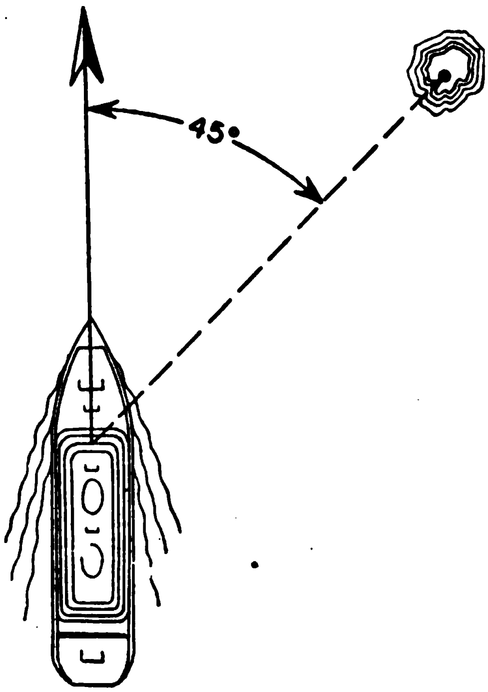


FIGURE 4.

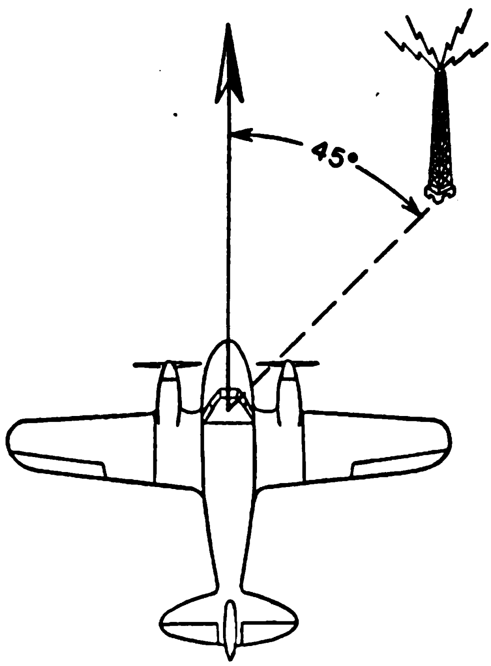


FIGURE 5.

the nose (or bow) will change. Without a knowledge of the course being flown, this information would be of little value in determining a line of bearing. If, however, a known course were being flown and the aircraft were making good a definite geographical track, the bearing relative to the nose would determine the position of the aircraft along its flight path relative to the known position of the radio station. It is, therefore, obvious that a correlation between the bearing relative to the nose and the course being flown is necessary in order to determine the line of bearing of the aircraft from or to the known position of the radio station.

d. This correlation is accomplished by adding the bearing relative to the nose to that of the course being flown as observed from the magnetic compass or the directional gyro. If the sum total of these

bearings is greater than 360° then 360 will have to be subtracted from the total to find the actual magnetic bearing toward the radio station. An example is illustrated in figure 6, where the course being flown is 45° and the bearing relative to the nose is 45°. Thus the true bearing (magnetic) of the station is the sum of the two arcs, or 90°. It will be seen that the magnetic compass is a very important part of any radio compass navigation system, and any error in the magnetic compass will cause the computed radio bearing to be in error proportionately.

e. Figure 7 shows an airplane flying a course of 240°, and a bearing is taken which shows the radio station to be 250° (using an azimuth indicator as shown in fig. 8) relative to the nose of the airplane. By adding the radio compass bearing to the magnetic course, a figure of

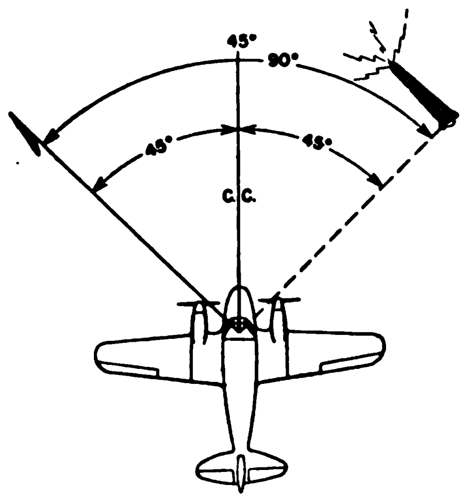


FIGURE 6.

490° is obtained. Obviously this is greater than 360° and therefore 360 must be subtracted from this figure, which shows the magnetic course toward the radio station to be 130°.

f. A variation of this method must be exercised when the radio compass azimuth scale is split as shown in figure 9. In this case the bearing indicated is also relative to the nose of the plane but is designated as port or starboard bearings. Starboard bearings (as indicated on the azimuth scale) are additive and port bearings are subtractive from the magnetic course. In any case where the sum total of the radio compass bearing and magnetic course is greater than 360°, the figure 360 should be subtracted from the sum total to obtain the computed magnetic bearing of the station from the airplane.

22. Establishment of fixes.—Thus far we have been concerned with the establishment of lines of bearings only. If while maintain-

ing position on a radio beam a line of bearing is established, the resultant of the two lines (radio compass computed bearing toward the station and radio range course) extended to a point of intersection will establish a position of "fix." A fix may be obtained by developing

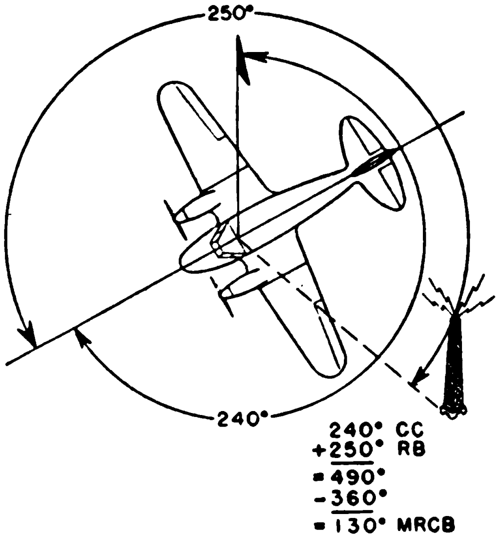


FIGURE 7.

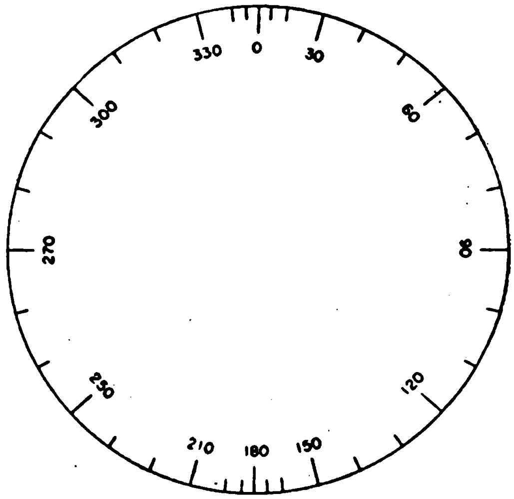


FIGURE 8.

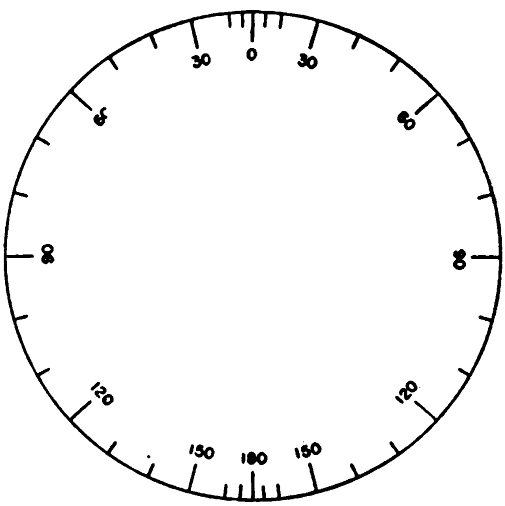


FIGURE 9.

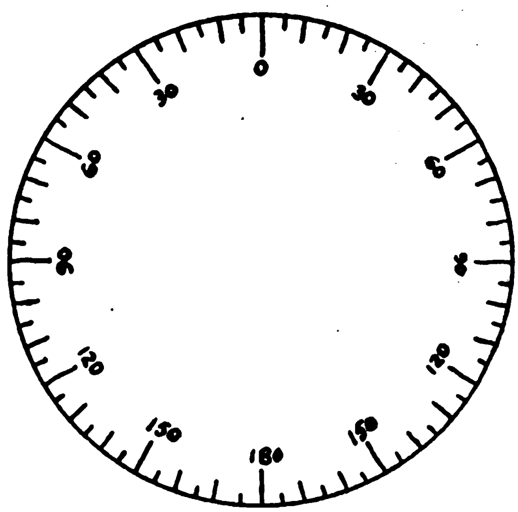


FIGURE 10.

two lines of bearings from two stations separated geographically sufficiently to produce a differential in bearing greater than 30°. A line of bearing from a third station will materially aid in determining the accuracy of the fix computed from two stations (fig. 12).

23. Magnetic variation.—Thus far no allowance has been made for the factor of magnetic variations as published on all aeronautical charts. Inasmuch as any error of the magnetic compass will cause

an error of equal magnitude in the computed radio compass bearing, it is obvious that variation affecting the magnetic compass must be taken into consideration in computing radio compass bearings. The factor of variation may cause errors of as much as 25°, depending on

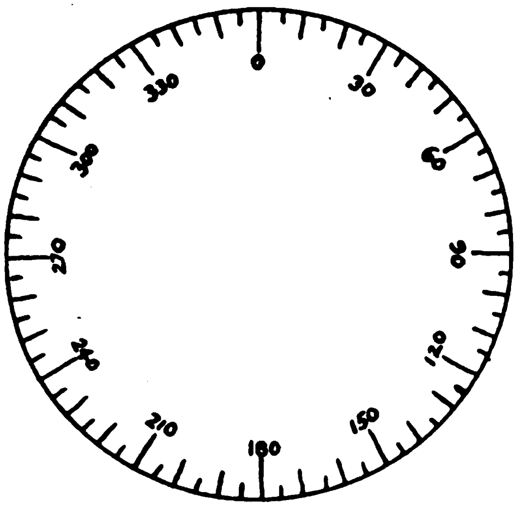


FIGURE 11.

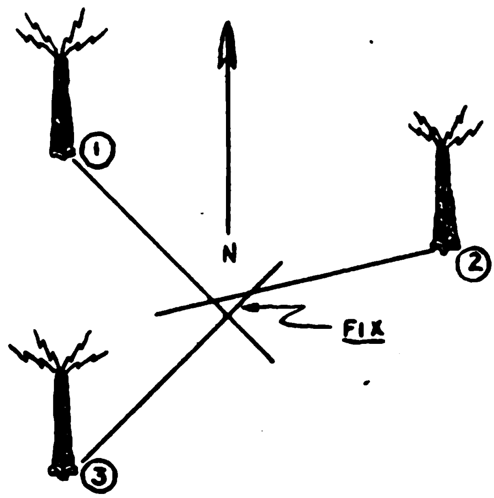


FIGURE 12.

the particular section of the country over which the airplane may be flying. Variation should be added or subtracted, as the case may be, based on the advertised variations existing at the approximate location of the airplane rather than at the radio station. In general, it is permissible to disregard the difference of variation existing between the aircraft's location and the radio station when the distance involved is not greater than 100 miles. However, this factor should be reckoned with, if bearings are taken over long distances, particularly in the extreme northeast and northwest sections of the United States where the lines of equal variation are close together.

24. Magnetic compass deviation.—Magnetic compasses aboard aircraft are usually compensated only at the northeast, south, and west points. The error existing at other points of the compass is usually determined and shown on a correction card attached to or near the compass. This error may be as great as 5° or 6°. For greatest accuracy in computing radio compass bearings this error must be taken into consideration and should be added to or subtracted from, as the case may be, the magnetic (as observed) heading of the aircraft and the corrected course used as a basis for computation of radio compass bearings.

25. Radio compass deviation.—*a.* Generally speaking, radio waves follow the path of least resistance, and as a rule it may be assumed that for the band of frequencies covered by the average radio

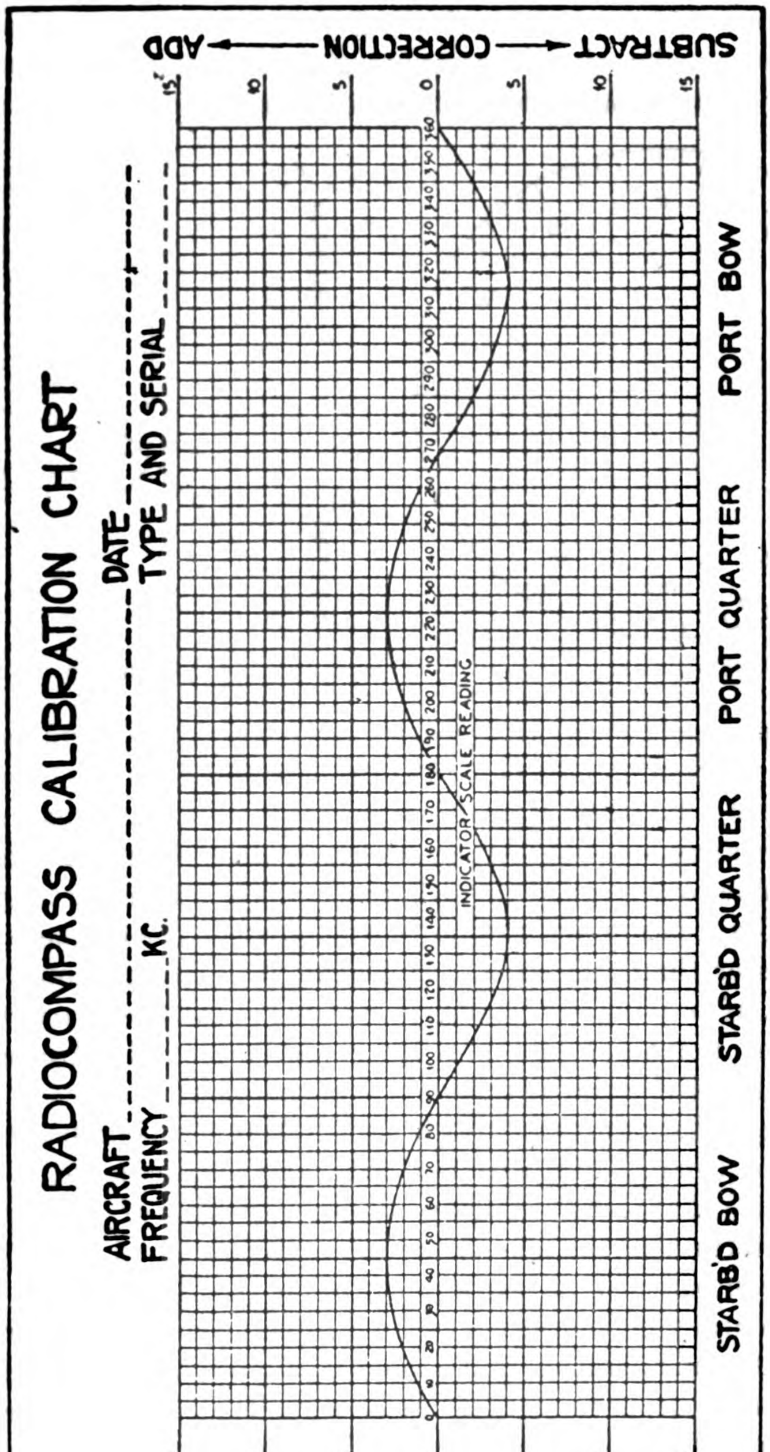

RADIOCOMPASS CALIBRATION CHART
AIRCRAFT
DATE
FREQUENCY
KC.
TYPE AND SERIAL
ADD ← CORRECTION → SUBTRACT
INDICATOR SCALE READING
STARB'D BOW
STARB'D QUARTER
PORT QUARTER
PORT BOW

FIGURE 13.

compass this path of least resistance is a straight line from the transmitter to the aircraft aboard which the radio compass is installed. The higher conductivity of the metal in the aircraft tends to distort the wave front of the station in the near vicinity of the aircraft. This phenomenon is evident in large all-metal aircraft to a greater degree than in smaller ships, but its presence is pronounced in all types of aircraft. The loop antenna of the radio compass is therefore subjected to this distorted field, and erroneous bearings will result if the physical rotation of the loop antenna relative to the nose of the aircraft is read directly from a conventional azimuth scale such as shown in figure 8 or 9. Fortunately, it is possible to make a calibration chart for such errors, and a typical chart is shown in figure 13.

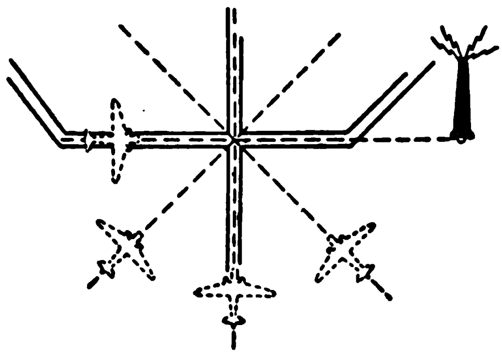


FIGURE 14.

b. The only entirely satisfactory method of preparing such charts is to ascertain the error during flight. Any bearings taken while on the ground may be subject to error due to reflections from buildings, power lines, etc. Also, the aircraft will not be in normal flying position, especially if it is of the type utilizing retractable landing gear, and the tail-down position will introduce error. The most satisfactory method of flight calibration is to select a day when the wind is less than 8 miles per hour in order to avoid excessive drift angles. A highway which is in direct line with a radio range or broadcast station should be selected and used as a reference point. The position of the highway being used during these calibration flights should be not less than 15 or more than 50 miles from the radio station (fig. 14).

c. The method of calibration is substantially as follows: With a plain paper disk pasted over the azimuth scale usually furnished with the equipment, the ship is flown exactly down the highway at an altitude low enough to overcome parallax effect. The loop is then rotated to obtain the desired response on the indicating instrument (needle centered or null in earphones), and the position of the needle on the azimuth scale is then marked on the blank paper disk. At this

time the directional gyro is set exactly to 0°. A turn is then made and the plane is flown back across this road at a predetermined point at an angle of 15° port or starboard, and the position of the azimuth indicator is ascertained and marked to correspond to the 15° angle. This maneuver is repeated for each of the 15° points around the compass. Greater accuracy may be obtained by changing course 10° instead of 15°, but it is usually easy to interpolate the results between the known points. The results can be transferred to a permanent disk to replace the evenly graduated azimuth indicator (figs. 10 and 11).

d. Another method of calibration is to fly the course exactly as described above, making note of the difference between the evenly graduated azimuth scale and that registered by the azimuth needle. This difference will be expressed as so many degrees to be added or subtracted as the case may be. From these data a chart may be drawn similar to that shown in figure 13. In this case it will be necessary to refer to the chart with each bearing and make the necessary correction by adding or subtracting the difference between the indicated and the true bearing.

e. Still another variation in automatic correcting for error due to distortion of the wave front is to employ a cam device as a part of the azimuth indicator which will automatically retard or accelerate the speed of the azimuth needle to compensate for the error. This cam is cut on the basis of the error determined in any of the approved methods of calibration and will permit the use of any evenly graduated azimuth scale. With the evenly graduated scale it is possible to rotate this scale independently of the movement of the azimuth needle. This will permit the scale to be set to a lubber line representing the nose of the airplane. With the scale thus rotated to the course being flown, true magnetic bearings will be indicated without the necessity of computation. A simplification (from a navigation viewpoint) of this device would be to use a compass "repeater" to maintain the radio compass azimuth scale in synchronization with the plane's magnetic or directional gyro compass, which holds its position relative to magnetic north irrespective of the movement of the ship or rotation of the radio compass loop.

f. Another very effective method of calibration is effected by locating accurately a transmitter with a vertical antenna not less than 500 yards from a compass swinging table. Elevate the tail of the plane to a level flying position and swing the plane. In locating the transmitter, guard against positions near large buildings or power lines.

g. Two calibration curves should be made, one near 1638 kc for the 700–1700 kc band and one near 500 kc for the 200–700 kc band. Normally there is a difference of about 2° between these two bands.

26. Homing.—*a.* Homing is the most important function of D/F equipment since, in the final analysis, the most important phase of navigating the airplane is the arrival at its destination. By taking bearings on a surface transmitter at the point of destination, the aircraft can "home" on this station until the station is in sight or until the aircraft is over the transmitting station. When used in this manner, any errors in the radio compass *decrease* as the plane approaches the transmitting station and finally become negligible.

b. The two general methods of using the radio compass as a homing device are as follows:

(1) The operator takes bearings on the transmitter at point of destination and keeps the pilot advised of these bearings. As the destination becomes nearer, bearings are required at more frequent intervals. If an approach is being made with low visibility, bearings should be practically continuous for the last 10 minutes or so, and the pilot advised, by hand motion (or remote dial), as the minimum deviates away from 0° (or other heading if allowance is being made for wind drift). The operator can judge from signal intensity increase when the airplane is nearing the transmitting station. During this last part of the approach there will not be sufficient time to record the bearings, as the operator should watch the scale continuously and signal to the pilot.

(2) The loop is locked in position at 0° (or off 0° to allow for cross wind if necessary) and transmission from the point of destination is tuned in by the operator. The pilot then puts on a headset and keeps the airplane turned for minimum signal. If the drift is to be compensated, in order to fly over a straight course so that the aircraft will not be flown downwind, the loop should be offset by an amount corresponding to the drift. In setting the loop to compensate for the wind drift, use the following rules:

a. If the wind is from the *right* (starboard) the loop is set below 0° (i. e., 350°–340°, etc.).

b. If the wind is from the *left* (port) the loop is set above 0° (i. e., 10°–20°, etc.).

c. The practical limitation of method *b*(2) above is evident in that if the ship is flying in smooth air it is necessary for the pilot to kick the rudder frequently to make sure that the "minima" path is being followed; otherwise there is no positive indication that the ground transmission continues to be received.

d. If the ship is flying in turbulent air, and the minimum is sharp, it is very difficult and sometimes impossible to keep the heading of the ship set for minimum signal.

e. In case of an instrument approach the pilot may desire to determine, with the D/F, when the plane is passing over the transmitting station. This is difficult when using method *b*(2) above because it is not always possible to know whether a very loud signal is caused by loss of minimum (over the station) or due to the ship turning slightly (a short distance away from the station). Therefore, in case the pilot wishes to determine, with the D/F, when the plane is passing over the transmitting station, it is generally best for the radio operator to take the bearings and determine "overhead." This is determined by noting that as the plane approaches close to the transmitting station the signal intensity increases, making it necessary to turn back the volume control to a point near minimum volume. Just before the plane passes over the station the minimum will broaden, and when the plane is over the station (in the "no minimum" zone) the minimum will disappear entirely. At the same time there will be a rise in signal intensity; this will be quite rapid and pronounced if the altitude of the plane is not substantially greater than the minimum heights tabulated below. As the altitude increases this intensity, rise naturally becomes more gradual. In order definitely to establish loss of minimum the loop should be rotated back and forth continuously (through the null point) after the volume control has been turned back to reduce volume. With this procedure the operator will see (and hear) the minimum broaden and disappear as the plane approaches closely and passes over the transmitting station, also reappearance and sharpening of the minimum when the plane has passed beyond the station.

f. The "no minimum" zone over the transmitting station is in the form of an inverted cone about 20° in diameter. Therefore, as the altitude of the plane increases the area of the "no minimum" zone increases. Due to the necessity of a time interval of 4 to 5 seconds to observe and check the loss of minima, it is advisable to maintain the following minimum altitudes (above the station) when obtaining an "overhead" check with the D/F:

Speed of plane (mph)	*Minimum height above station* (feet)
90–100	2, 500
140–150	3, 500
180–200	4, 500

A good radio operator with a little practice can become quite accurate with a D/F "overhead" at 120 mph at 1,200 feet.

g. Although better results can be obtained in "overheads" by the radio operator than by the pilot, it is highly practical for the pilot to determine his own "overhead" with a little practice with either of the following methods:

(1) When the pilot approaches fairly close to the station, the sensitivity of the indicator needle should be adjusted almost to the point of maximum sweep. He should constantly "fish tail" the ship a small amount so that the needle will vary slightly across the zero indication. By cross-checking the sweep of the directional gyro while "fish tailing," the broadening of the minima zone over the station will be indicated by a sluggishness of the needle just before the needle reaction to the rudders reverse as the plane passes over the station.

(2) It is possibly a little easier to detect the "overhead" if the loop position is used giving a null. Check the null constantly by "fish-tailing" just enough to check the signal each side of the null as the plane approaches the station. Near the "overhead" the signal volume will increase very perceptibly; the null will sharpen first and then broaden out to a "no minima" signal as the plane passes over the station.

h. Summary of D/F homing and overhead procedure:

(1) Radio operator follows minimum and gives bearing to pilot. For fixed loop pilot will follow homing procedure.

(2) Follow minimum closely and keep swinging back and forth through it so as to observe when it begins to broaden. "Fish tailing" will accomplish this for fixed loop.

(3) Just before passing over station, minimum will begin to broaden and then will disappear completely when overhead. Minimum will reappear and sharpen when passing beyond station.

(4) When passing over station there will be a marked increase in signal strength. The modulated signal will increase rapidly in volume.

(5) If the plane passes to one side of the "no minima" zone the minima will not disappear but will move rapidly around the dial. If minima move clockwise, the station is on the right. If minima move anticlockwise the station will be on the left.

(6) Volume should be kept at a comfortably low level.

27. Operating notes in taking bearings.—*a*. The next most general use of the radio compass is taking bearings on surface transmissions. Except when very close to the transmitting station, the minimum or null is not sufficiently sharp to read. There may be several degrees through which, as the loop is turned, the signal volume is either inaudible or a minimum. This inaudible zone is usually known as the split. In this case the loop is turned in both directions, just

beyond the minimum zone, where the signal intensity is judged to be equal. With a little practice, these two points of equal signal intensity can be judged quite accurately. The middle point of this split is then used as the observed bearings. When the noise level is extremely high it may be necessary to take a series of readings until at least three correspond quite closely. These can then be averaged and plotted for the average time taken for the three readings. The airplane heading (magnetic) should be taken simultaneously from the compass (corrected).

b. The corrected radio bearing added to the airplane heading gives the bearing to the transmitting station in degrees from magnetic north. If the sum of these two exceeds 360°, then subtract 360 from the sum to obtain the correct magnetic bearing. To convert a "magnetic" bearing to "true," add or subtract the magnetic variation, at the location of the plane, using the following rule:

If magnetic variation is *east*, *add* to obtain true.

If magnetic variation is *west*, *subtract* to obtain true.

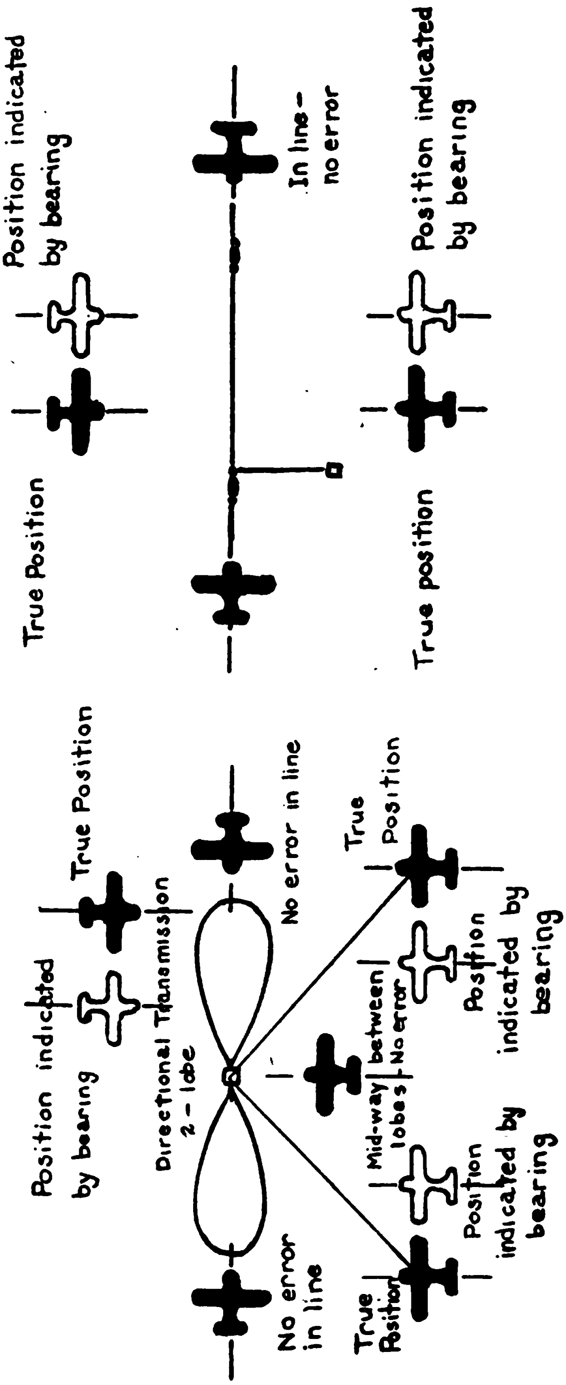
28. Types of antenna for surface transmitters.—*a.* When taking bearings on surface transmitters, a careful check on the type of antenna used should be made. Vertical and symmetrical T-antennas are preferable for bearings. Errors may be experienced when bearings are taken on directional transmission, also on transmissions from a long inverted L-antenna if a good ground is not used under the entire length of the flat top. Figure 15 shows positions of the airplane for zero and maximum errors for both cases. In general, bearings on radio range stations are satisfactory.

b. Avoid taking bearings on a surface transmitting system radiating a horizontally polarized wave because of the possibility of large D/F errors resulting from this type of transmission (90° maximum).

c. In most cases broadcast stations are very satisfactory since they use vertical or symmetrical T-radiators. However, in the case of simultaneous transmission on the same frequency by two stations, check carefully to determine which one of the stations the bearings are being taken on.

d. Marine beacon stations are very satisfactory since they radiate vertically polarized waves.

29. Checking ground speed with D/F.—*a. General.*—Bearings on surface stations which are substantially abeam the aircraft are useful for checking the ground speed of the flight, or the distance to the surface station, one of which must be known. The chart (fig. 16) consists of five vertical parallel scales representing: *elapsed time* (minutes required for the bearing change); *rate*, *aircraft ground speed*



① Error introduced by directional transmission.

② Error introduced by L-type-antenna. (Note that heading does not affect this error.)

FIGURE 15.

(knots); *distance traveled by plane* (nautical miles); *change in bearing (degrees)*; and *distance from station* (nautical miles). It is also possible to utilize bearings from a ground D/F for this purpose. If the ground D/F is of the loop type the fixed antenna must be used for transmission due to inherent errors in "abeam" bearings when using the trailing antenna (fig. 18).

b. The chart is used by lining up the two known factors (T and R or B and D) with a straightedge which intersects the P scale. This point is then lined up with the third known factor scale. The result is indicated where the line crosses the desired factor scale.

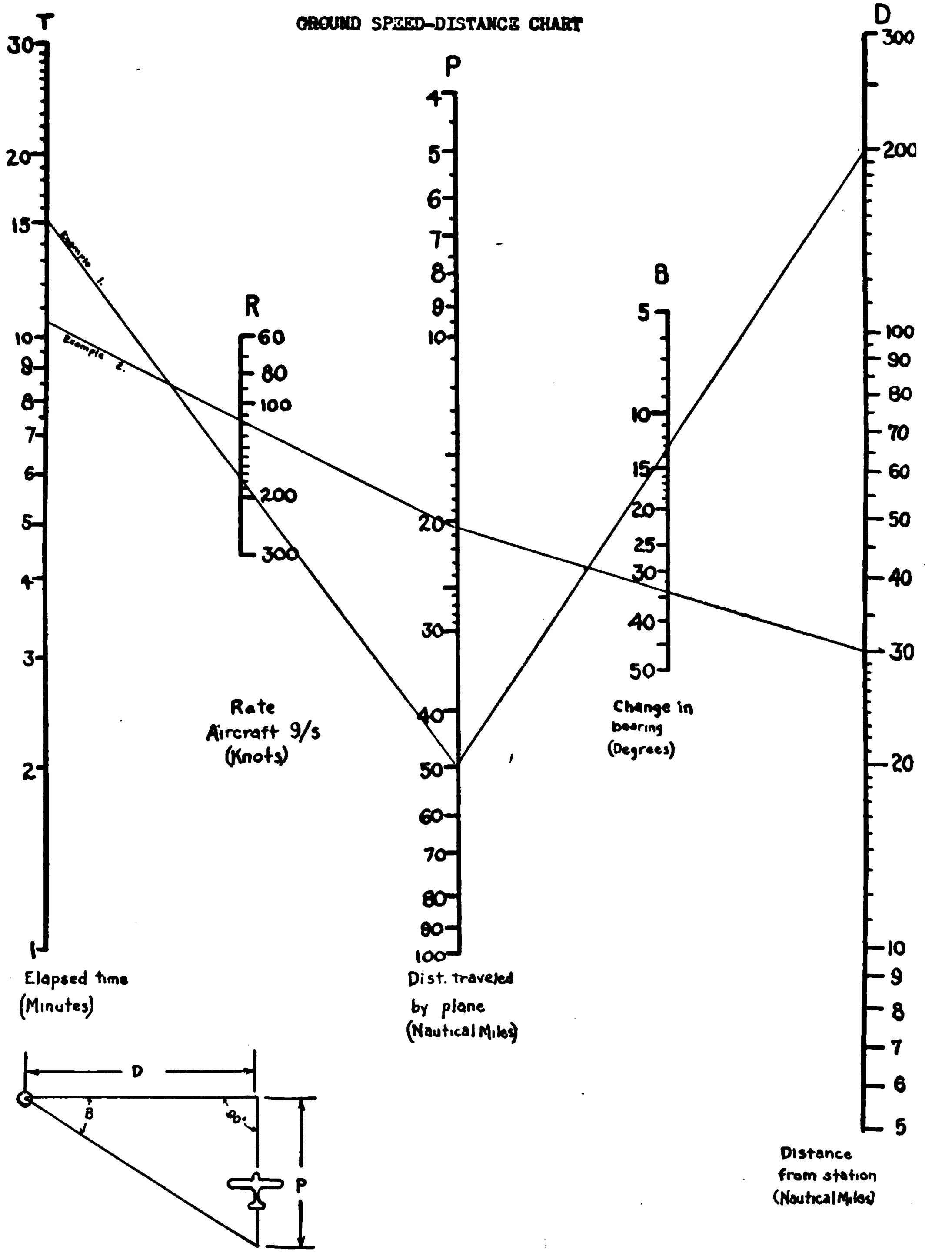


FIGURE 16.—Ground speed—distance chart.

c. It is possible to eliminate the first step in the graphic solution if the distance traveled by plane (nautical miles) is known or computed by some other method. The following examples will clarify the use of this chart:

(1) *Example No. 1.*—The airplane is passing a surface station abeam and 15 minutes are required for the bearing (on the surface station) to change from 90° to 104°. The ground speed of the airplane is 200 knots. As shown on the chart the plane is about 200 nautical miles from the station.

(2) *Example No. 2.*—The airplane is passing a surface station abeam at a distance of 30 miles. Ten minutes and thirty seconds are required for the bearing (or the station) to change 34½° (say from 304½° to 270°). The ground speed of the aircraft as shown on the chart is about 118 knots.

d. Since this solution is applicable principally over water or over vast unmapped land areas, it is scaled in nautical miles for use on charts.

30. Night effect and other similar effects.—*a*. Reduced to simple terms, "night effect" as applied to the operation of a D/F consists of shifting (slow or fast) and indefinite minima, or entire absence of minima. All loop type radio compasses are subject to "night effect" although the rotatable loop aboard the airplane (in flight) is *much less* than a loop on the surface.

(1) Generally speaking, night effect is not experienced during daylight hours, i. e., about 2 hours after sunrise to 2 hours before sunset. However, it is possible to obtain similar effects if the arriving radio wave has traveled over a considerable amount of terrain consisting of alternate stretches of land and water, or over mountainous terrain. Further, these effects may be experienced when flying along a coast line if the arriving radio wave coincides with the coast line, or crosses the coast line at a small angle (less than about 30°). (See fig. 17 for a graphic representation.) Errors due to this last condition are generally referred to as "coast line refraction." In practice it will be found that these errors will vary considerably with different terrain conditions and may be from 0° to about 10°.

(2) The three conditions outlined immediately above are most likely to cause incorrect bearings, also shifting and/or indefinite minima where the plane is flying relatively low (2,500 feet or less above the surface), or if flying at an altitude less than nearby mountains which intervene between the aircraft and the transmitting station. This last condition may cause very erratic bearings. Referring to figure 17, note that *true* "coast line refraction" causes errors in opposite directions

for bearings taken with the *D/F on the airplane* and bearings taken by a *D/F on the ground.*

(3) Other conditions remaining constant, there is less tendency for shifting and indefinite minima during the summer and more tendency during the winter. At the Equator there will be a minimum seasonal change. North and south of the Equator the difference between summer and winter operation becomes greater as the latitude increases.

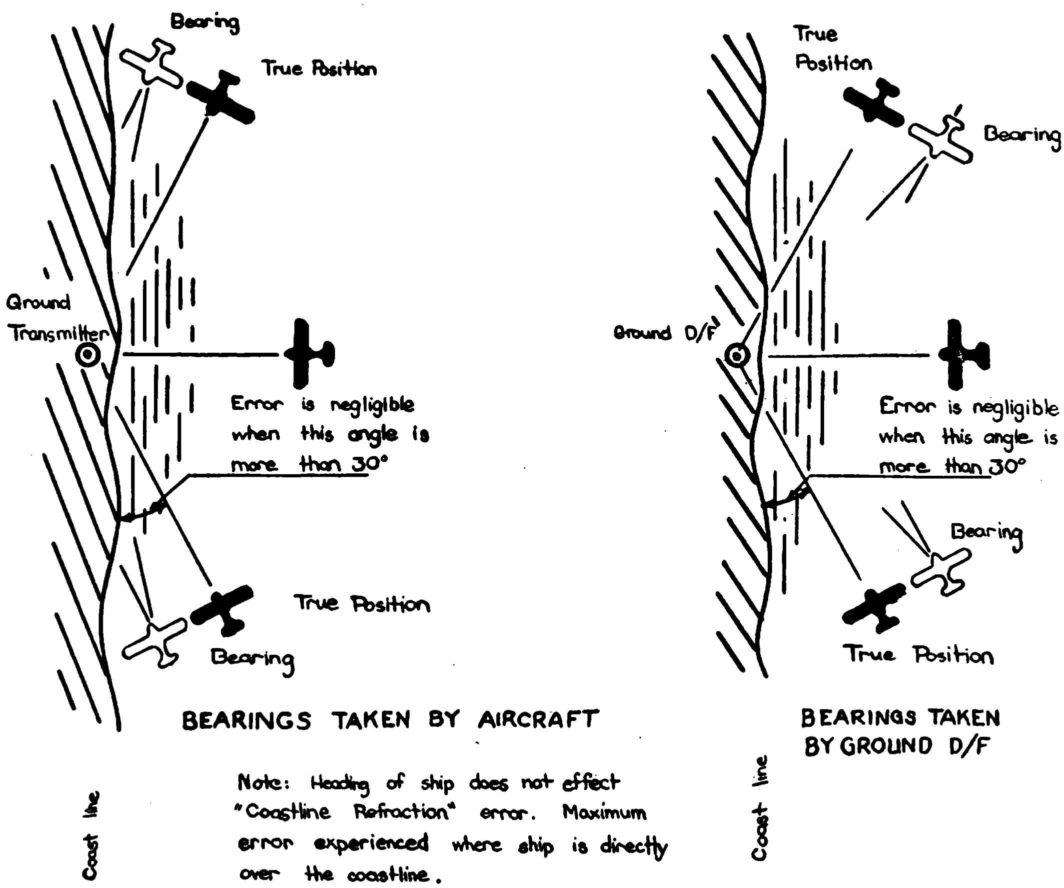


FIGURE 17.

(4) "Night effect" due only to time of day is most pronounced during sunrise and sunset periods. These effects are generally less pronounced after total darkness has set in.

(5) In general, shifting and indefinite minima are less pronounced on the lower frequencies (200–500 kc) and more pronounced on the higher frequencies (700–1700 kc).

(6) Experience has shown that reliable bearings (within 5°) may be taken with the aircraft D/F at night, provided a frequency in the approximate band 200–550 kc is used, and further provided that the

distance does not exceed about 200 miles. This assumes that there are no errors due to terrain or coast line effects.

(7) When night effect is experienced, note that it will disappear at some minimum distance from the station (where the direct ground wave predominates). This distance will vary from about 20 to 60 miles, depending principally on the following conditions:

(*a*) Frequency of transmission (less for higher frequencies, greater for lower frequencies).

(*b*) Time of day (minimum around sunrise and sunset; maximum just after total darkness has set in).

(*c*) Season (maximum—midsummer; minimum—midwinter).

(*d*) Latitude (seasonal variation greater as distance from Equator increases).

b. Night effect and other similar effects on bearings supplied by ground D/F stations.—In general, bearings taken by a loop type ground D/F station (on a plane in flight) are affected by the same conditions outlined in *a* above. However, these bearings are affected to a greater degree than bearings taken by the plane on a ground transmitter. There is a definite reason for this situation:

(1) In the case of bearings taken by a ground D/F station, the wave has traveled a considerable distance in contact with the earth's surface before arrival at the D/F station.

(2) In the case of bearings taken by the plane on a ground transmitter, the wave has traveled a considerable distance under relatively "free space" conditions before arrival at the plane.

c. Trailing antenna effect, ground station loop type.—When a loop type ground D/F is used to take bearing on a plane in flight, errors may be introduced if the trailing antenna is used for transmission and if the aircraft is not heading directly toward or directly away from the D/F station. This error is maximum when the heading of the aircraft is such that the D/F station is abeam. This error is caused by "horizontal component" in the transmitted wave and in practice may reach 45°. (Theoretically the maximum error is 90° but this is never approached with the type and location of trailing antenna used.) This error always causes the bearing to be behind the airplane. (See fig. 18.) This error is usually very small if sea water intervenes between the airplane and the D/F and if the airplane is at least 50 miles distant and not higher than about 2,000 feet above the surface. The magnitude of this error is governed principally by the following:

(1) Type of terrain between airplane and D/F (least for sea water, greatest for dry sandy soil).

(2) Altitude of airplane (error increases with increasing elevation).

(3) Distance of airplane from D/F (error decreases as distance increases).

d. Trailing antenna effect, ground station, Adcock type.—This error is not experienced when the ground D/F is of the "Adcock" type, although there is another effect, discussed below, which must be taken into account.

(1) Even with the airplane heading directly toward or away from the ground D/F station, it has been found that, in general, the minima are steadier if the fixed antenna is used for transmission on frequencies of 1638 kc and higher. This is true whether the ground D/F is of the loop type or Adcock type. This effect is due to arrival of two waves at the D/F station (when the trailing antenna is used for transmission), one by reflection from the earth's surface and the other direct or by reflection from the Heaviside layer; interference between these two waves causes the minima to shift and vary in width in many cases. Therefore, for close-in bearings by a ground D/F on frequencies of 1638 kc and higher, better and steadier minima will generally be obtained if the fixed antenna is used for transmission.

(2) This effect should not be confused with the conventional "trailing antenna effect" since, in the latter case, the minima may be steady and sharp and yet be in error by a considerable amount where the ground D/F is of the loop type.

31. D/F approach and let-down procedures.—*a.* The following three approaches and let-down procedures should be modified to conform to the particular problem or terrain situation:

(1) *"Boxing" the station.*—The principle of this system is to fly in the pattern of a square around the station while letting down to a predetermined altitude. Assume that the square will be flown on the cardinal headings. The station is approached from any direction and on the "overhead" indication the airplane is turned to the nearest cardinal point—assume that it is south—and flown for 1 minute. The plane is then turned 90° to east. Set the loop at 225° (relative bearing) and fly 1 minute on this heading, or until a null is indicated, whichever comes first, then turn 90° left again, heading north. Check the time when the airplane is abeam of the station—relative bearing 270°—and again continue for 1 minute, or until a null is observed on a relative bearing of 225°, whichever comes first, and turn left to a heading of west. The effect of this maneuver is to form a box pattern, each side of which is approximately a 2-minute leg. This box can be contracted or expanded, depending on the equipment, pilot ability, and terrain features.

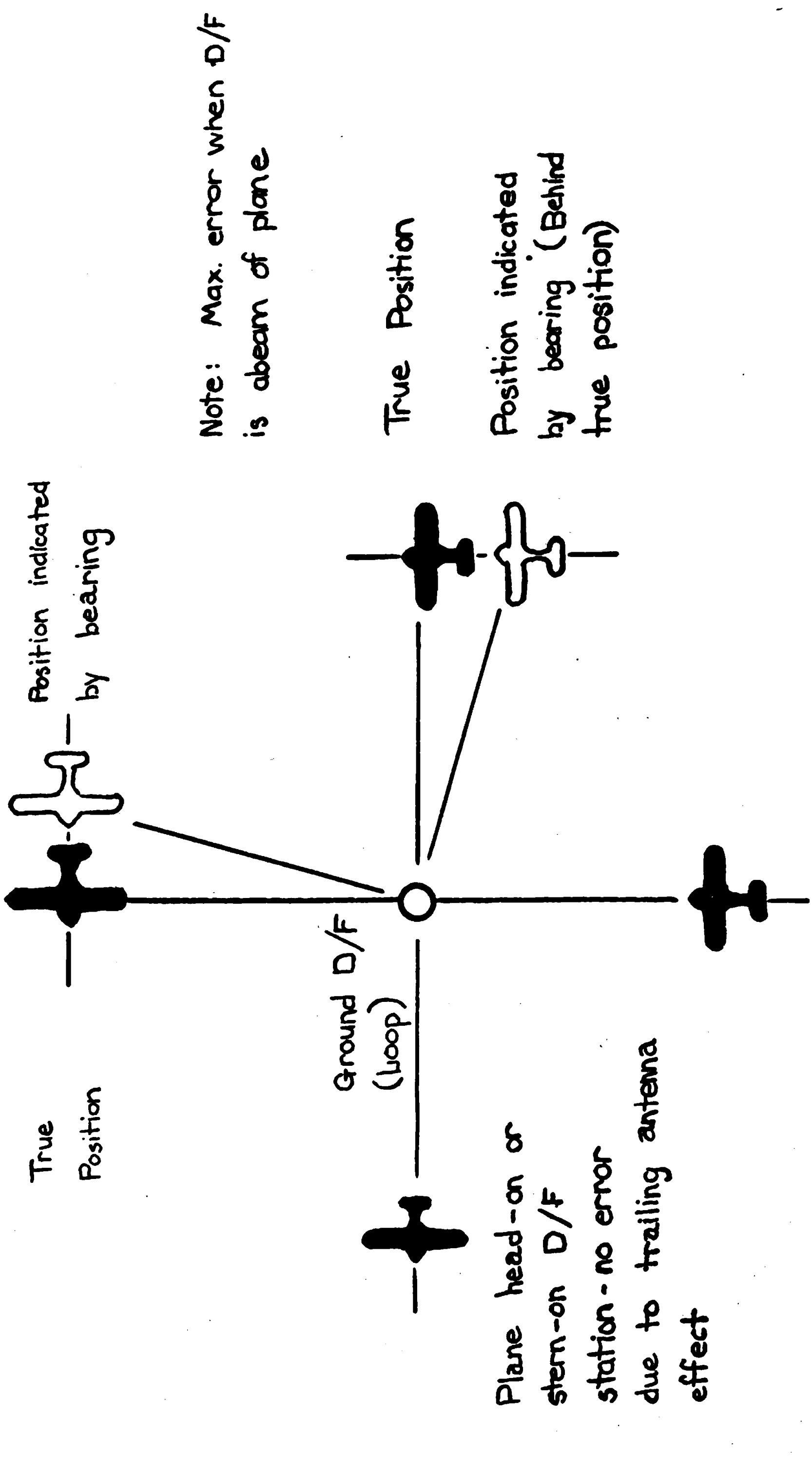


FIGURE 18.—Trailing antenna effect.

(2) *Flying the needle.*—The system known as "flying the needle" is highly efficient for a ship having a fixed loop. After the "overhead" is determined either by the right-left indicator or by the null method, the radio compass is switched to "Comp" position and the pilot begins a turn toward the direction in which the needle is pointing (or he may make the turn in either direction arbitrarily) and begin his let-down to predetermined altitude. The principle of this method is to make the let-down right over the station. If wind drifts the plane off, the direction of the R-L indicator needle will reverse, at which time the pilot reverses the direction of his turn, again flying toward the needle. The advantages of this method are its extreme simplicity and the fact that the plane is never at any time more than the diameter of one 360° turn away from the station until the break-through is accomplished.

(3) "*Blocking*" *the station.*—(*a*) Blocking the station may take many diversified forms, depending on the result desired and on the terrain. The normal result desired ordinarily is accomplishing an approach to the station over a given track or on a desired bearing. After determining which side of the station the airplane would pass, the loop is offset the amount of the relative bearing between heading being flown and the heading of the desired approach leg. When the null is obtained, the airplane is turned to the approach heading. Compensate this heading for drift by any method available, and with a small adjustment occasionally the desired track to the station will be made good.

(*b*) One variation of this is sometimes useful in "homing." Due to a high noise level, it is often desirable to know the approximate time of the overhead as closely as possible. When the airplane is reasonably near the station, a 45° turn is made in either direction from the homing heading. The loop is then set 90° to this 45° heading in the direction of the station. When a null is obtained, the plane is turned 90° toward the station and this is used as the homing approach. The time on the leg from the time when the 45° turn was made until the 90° turn was made will be approximately the same as the time from the 90° turn to the overhead. (In a triangle with angles of 90°, 45°, and 45°, the two legs opposite the 45° angles are equal.)

32. Range and accuracy.—*a.* The range of the aircraft D/F depends upon several factors:

(1) Power of surface transmitter and effective high of antenna.
(2) Frequency of transmitter (greatest range on high frequency).
(3) Stability and clarity of transmitted signal.
(4) Static level.
(5) Ignition noise level.

(6) Time of day (minimum range around midday).

(7) Season of year (minimum range—midsummer; maximum range—midwinter).

(8) Type of terrain over which wave travels (maximum over open sea, minimum over broken land and fresh water or over mountainous terrain). In view of the many factors affecting range it is impossible to set any figure which can be used generally. Experience indicates that, given 800-watt output into an efficient antenna, the range may vary from about 500 miles under ideal conditions on 1638 kc to about 25 miles under adverse conditions on 375 kc.

b. The accuracy of the bearings is affected by most of the eight factors listed above and in addition by yawing of the airplane. Also, in rough air the readings cannot be taken as accurately as in smooth air. Any errors in the ship's magnetic compass will also affect radio range bearings. With the airplane flying smoothly and without appreciable yawing with steady, well-defined minima, the errors should not exceed 5°. Therefore, a bearing taken under the most favorable conditions should be used with reservations that it may be in error by 5°. Under poor conditions, the radio operator should label as doubtful any bearings which he judges to be in error in excess of 5°.

33. Correction of radio bearings.—Although radio bearings are considered less accurate than results possible with dead reckoning, the development of radio equipment is making radio bearings more reliable. As radio bearings approximate arcs of great circles, they must be changed to mercator bearings before being plotted on a mercator chart. This correction is not considered necessary if the distance to the station or stations is less than 100 miles. The table following may be used to correct radio bearings. Enter table with midlatitude and DLo between the D. R. position and the transmitting station and pick out the correction necessary. This correction is additive/subtractive as the aircraft is eastward/westward of the station in north latitude, and subtractive/additive as the aircraft is eastward/westward in south latitude.

Example: An aircraft (D. R. position 32°40′ N., 121°15′ W.) receives a bearing of 271° from Imperial Beach (NPZ, 32°35′ N., 117°08′ W.).

Midlat., 33°; DLo, 4°; correction, +1.1°.
Mercator bearing, 272.1°.

CORRECTION REQUIRED TO CONVERT A RADIO GREAT CIRCLE BEARING TO MERCATORIAL BEARING

Difference of longitude of ship and radio station

	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°
66	0.9	1.8	2.8	3.7	4.6	5.5	6.4	7.3	8.2	9.1	10.0	11.0	11.9	12.8	13.7
63	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.1	8.0	8.9	9.8	10.7	11.6	12.5	13.3
60	0.9	1.7	2.6	3.5	4.3	5.2	6.1	6.9	7.8	8.6	9.5	10.4	11.2	12.1	12.9
57	0.8	1.7	2.5	3.4	4.2	5.0	5.9	6.7	7.5	8.4	9.2	10.0	10.9	11.7	12.5
54	0.8	1.6	2.4	3.3	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7	10.5	11.3	12.1
51	0.8	1.6	2.3	3.1	3.9	4.7	5.5	6.2	7.0	7.8	8.5	9.3	10.1	10.8	11.6
48	0.8	1.5	2.2	3.0	3.7	4.5	5.2	5.9	6.7	7.4	8.2	8.9	9.6	10.4	11.1
45	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.1	7.8	8.5	9.2	9.9	10.6
42	0.7	1.4	2.0	2.7	3.4	4.0	4.7	5.4	6.0	6.7	7.4	8.0	8.7	9.4	10.0
39	0.6	1.3	1.9	2.5	3.2	3.8	4.4	5.0	5.7	6.3	6.9	7.5	8.1	8.8	9.4
36	0.6	1.2	1.8	2.4	3.0	3.5	4.1	4.7	5.3	5.9	6.4	7.0	7.6	8.2	8.7
33	0.5	1.1	1.6	2.2	2.7	3.3	3.8	4.4	4.9	5.4	6.0	6.5	7.1	7.6	8.1
30	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.4
27	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.6	4.1	4.5	5.0	5.4	5.9	6.3	6.8
24	0.4	0.8	1.2	1.6	2.1	2.4	2.9	3.3	3.6	4.0	4.4	4.8	5.2	5.6	6.0
21	0.3	0.7	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.6	3.9	4.3	4.6	5.0	5.3
18	0.3	0.6	0.9	1.2	1.6	1.9	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.3	4.6
15	0.3	0.5	0.8	1.0	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.1	3.3	3.6	3.8
12	0.2	0.4	0.6	0.8	1.0	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1
9	0.2	0.3	0.5	0.6	0.8	1.0	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	2.3
6	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6
3	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8

In north latitude if the station from which the radio bearing is received lies to the west of ship's position, the correction is additive; if to the east, the correction is subtractive, the mercatorial line of bearing being on the equatorial side of great circle line of bearing. In south latitude the rule is reversed. (The bearings must always be laid off from the radio station.)

SECTION III

ALTIMETERS

34. General.—*a.* The altimeter is deemed such an important instrument that a separate section is devoted to it. A recapitulation of the many recent accidents wherein the airplane almost—but not quite—cleared certain elevations leads one to believe that a lack of operating knowledge of the altimeter might be a contributing cause.

b. This short treatment of altimeters is not to be construed as being a complete picture of all that the pilot should know concerning them, but it is a brief résumé of the important points from an operational standpoint. The pilot should supplement this with a thorough study of T. O. 05-30-1 and other authoritative works such as Irvin's *Aircraft*

Instruments, etc. At this time there is no single book which can be recommended that contains all the information about altimeters and their use. There are many good books on this subject, each of which will contain features of value to the pilot, and so every opportunity should be taken to study each author's text and coordinate the various features.

35. Description.—*a.* This instrument is basically an aneroid barometer. It measures the weight of a column of air above the instrument. Since this column of air is a variable factor and not strictly uniform in density, a great many factors must be considered. That this instrument is extremely delicate and sensitive is apparent when it is realized that the motion of the evacuated cells is less than 3/16 of an inch, yet this motion will drive the large hand on the dial around 35 complete times or approximately 23 feet of pointer tip movement. Since the temperature range is so great (−35° C., +45° C.) no lubricant can be used, yet the especially hardened steel point tips operating in jewels are almost frictionless. Extremely small specially cut gears multiply the movement of the cells, translating the longitudinal motion into rotary motion of the hands.

b. There are two types of altimeters, the "standard" type and the "sensitive" type. In the Army Air Forces only the latter is considered. Although this type may be equipped with barometric window or with barometric window and index pointers, the latter is the most common type and is gradually replacing the former.

c. The zero position of this instrument is sea level condition of standard barometric pressure, 29.92 inches of mercury and temperature of 15° C. This instrument is calibrated for standard temperature gradient defined by N. A. C. A. as a 2°C/1000 feet decrease in temperature as the altitude increases. Any variation from this standard gradient must be taken into account before any information can be taken from this instrument.

36. Definitions.—*a. Altimeter setting.*—The figure set on the barometric window—called the "Kollsman number"—which is the barometric pressure at any given point corrected to standard sea level conditions.

b. Pressure altitude.—The apparent elevation at any given point with the altimeter set at standard sea level conditions.

c. Pressure altitude variation.—The difference between pressure altitude and the surveyed elevation at that point.

37. Setting the altimeter.—*a.* There are three types of problems in which an altimeter is the critical instrument with the pilot: traffic altitude, obstacle clearance, instrument landings.

(1) *Traffic altitude.*—This is maintained by setting the altimeter on the altimeter setting given by the nearest CAA radio station. This setting does not show the pilot the exact altitude above the ground, nor the exact altitude above sea level, nor the exact altitude above anything, but it does establish a reference plane whereby all aircraft in that vicinity will be spaced in such a manner as to provide traffic clearance.

(2) *Obstacle clearance.*—In clearing an obstacle, many factors have to be considered. Of the several methods for finding a true altitude some possess advantages over others. One may be a closer approximation than another. Yet due to physical limitation the exact altitude is almost impossible to find. Various computors and charts are available to give a very close approximation to the true altitude. If the temperature only at the airplane is known, it may be used with the pressure altitude at that elevation to correct the indicated altitude to a figure approximating a true altitude. If the ground temperature is also known, an average between the ground temperature and the temperature at the airplane, used in conjunction with the pressure altitude, will give a closer approximation of true altitude. If the temperature at various altitudes between the ground and the airplane is shown and plotted, a mean line can be drawn which will give a mean temperature to use in conjunction with pressure altitude and which will give the closest approximation of true altitude. (See T. O. 05-30-1 for theory of computation.) It is not sufficient to use the "altimeter setting" and traffic altitude given to clear dangerous obstacles such as mountains. When over such terrain it is usually impossible to obtain a ground temperature or temperature between the ground and the airplane, so the temperature at the plane has to be used. To check the actual altitude of the plane, the indicated altitude should be noted (altimeter set on last "altimeter setting") and then, without changing altitude, the altimeter indices should be zeroed (barometer window reads 29.92 inches). The pressure altitude is then read directly. This altitude should be corrected for the temperature at the plane. As an example, assume that the PA is 10,000 feet, outside temperature is 40° C. (a temperature encountered not infrequently), the actual altitude is approximately 8,670 feet, showing that the plane is 1,330 feet too low if a level of 10,000 feet is to be maintained. Climb the plane up to the estimated level for this calculation and again go through the same procedure to check the altitude at the new level. As a rule of thumb, when the altimeter is set to read pressure altitude, add 2,000 feet to the altitude of the obstacle and use this figure for the indicated pressure altitude for clearance.

(3) *Instrument landings.*—The third problem involves the setting of the altimeter for an instrument landing and a thorough knowledge of the errors which will affect the altimeter setting.

(*a*) With the altimeter set showing the local "altimeter setting" in the barometric window the plane will land when the altimeter shows the surveyed elevation of the field (neglecting errors).

(*b*) With the indices set at "pressure altitude" the plane will land at zero.

(*c*) With the indices set at zero the plane will land at the "pressure altitude."

(*d*) With the indices set at "pressure altitude variation" (plus or minus) the plane will land at the surveyed elevation of the field.

(*e*) With the altimeter set showing the local "altimeter setting" in the barometric window the plane can be flown on the proper traffic level.

b. For conversion between "altimeter setting" and "pressure altitude" the following form is extremely easy to visualize mentally for rule of thumb work, and will prevent mental confusion and stupid errors while this computation is worked out under conditions of mental stress.

Altimeter setting	29. 92	−30. 07	−.15″
Known field elevation	672		10
PAV	−150		−150′
PA	522		

(1) Always subtract the altimeter setting from standard 29.92 inches.
(2) Carry the same sign found in upper right box all the way through, adding or multiplying algebraically.
(3) For rule of thumb, a variation of 10 feet per 1/100 inch change of inches of mercury is used.
(4) Work across the top, down the right, and back to the left.
(5) This solution is sufficiently accurate for approach break-through problems, but for instrument landings the altitude pressure table should be used. In this problem, the actual PAV is 137 feet, or an error of only 13 feet.

38. Errors.—There are several sources of errors in altimeters which should be thoroughly understood by pilots: scale errors, hysteresis errors, friction errors, temperature errors. There are other errors such as position, installation, case leak, and vibration errors but the first four are the only ones the pilot need be especially concerned with.

a. Scale error is defined as the algebraic difference of the standard pressure altitude and the indicated altitude when the altimeter is subjected to the pressure corresponding to the standard altitude (altitude chamber test). For this error a chart should be made and revised periodically.

b. Hysteresis error is covered fairly thoroughly in the Technical Order. The following points, however, should be kept in mind by the pilot. The altimeter always lags behind the progress of the plane, whether it is ascending or descending. The amount of this lag depends upon the rate of change of altitude and the age of the instrument. The greater the rate of change, the more the altimeter lags. The older the instrument, the greater the lag due to the metal in the diaphragm losing some of its elasticity. Since these errors are additive, they can be combined into one curve. It is impractical to run curves on each altimeter for various rates of descent, since conditions would change constantly. The curves would have to be redrawn periodically as the instrument ages. However, the pilot can reduce these errors to a certain extent. If a large descent is made, the pilot can reduce the rate of descent to a small amount toward the end of his let-down and let the altimeter "catch up," so that the error will be less. If practical, the pilot should fly around a few minutes after a long descent at the lowest safe altitude permissible before beginning his instrument approach. If the pilot uses the same equipment daily, he can check this lag during contact landings over the same approach at each field and be able to estimate this lag very closely. Under normal conditions of instrument approach, the pilot should expect the instrument to be in error from a small amount up to 60 or 70 feet. As much as 100 feet may be experienced if the instrument is not in excellent condition. With steep descents, the error may be as large as 200 feet.

c. Friction errors may be reduced to a minimum by tapping the case of the instrument with the fingers as the let-down is made.

d. Temperature errors take two forms. The first, being the temperature of the metal of the instrument, is automatically compensated for within the instrument. The second, which is the temperature of the atmosphere, has already been described in paragraph 36*a*(2). This error is sometimes called the "inherent error" which directly affects the variable quantity being measured—weight of the atmosphere. If the exact altitude is to be measured as closely as possible, the outside thermometer must also be correct for the air speed of the plane before its reading should be used.

PART TWO

INSTRUMENT FLYING TRAINER, OPERATION AND TRAINING

CHAPTER 1

BASIC COURSE IN TRAINER

SECTION I

OPERATION

39. General.—*a.* The aim of part two of this manual is to present a comprehensive text covering all phases of instrument flying instruction and practice, including approach and let-down procedures and instrument landings. While it is possible to give courses of instructions in the above phases of instrument flying in aircraft "under the hood," it is far more economical in time and in equipment to utilize the instrument flying trainers for a large part of such courses.

b. This manual is written to serve as a guide for instrument flying trainer instructors, but is arranged to serve as a reference for pilots as well. Except where the context precludes, all phases of instruction are applicable to the instrument flying trainer as well as to aircraft.

c. The operation of the instrument flying trainers is covered in this manual. Refer to Air Corps Technical Orders for maintenance instructions. The following is applicable to the instrument flying trainer only.

40. Unlocking and locking trainer.—*a. Type C-2 and C-4 instrument flying trainers.*—(1) *Unlocking.*—With the student seated in the trainer, warn him not to turn the switch on or off until asked to do so. While steadying the trainer with the right hand on the handgrip under the tail, release the rear locking strap with the left hand. Holding the trainer in a slightly nose-down position with the right hand, hook the left thumb around the side locking strap. Give the order to "switch on" and as the motor starts release the side strap.

Until air speed is built up above stalling speed the trainer will try to spin. Still holding the tail handgrip, the instructor should steady it until rudder control is attained.

(2) *Locking* (be sure the "rough air" is turned off).—Secure the side strap first while steadying the trainer with the right hand on the stick or wheel. The rear lock may be maneuvered into position by using the longitudinal control in the rear fuselage with the right hand engaging the lock strap with the left. As the strap approaches the locking position, ask for "switch off" in a loud tone as the student probably is still wearing the headset. Swing the trainer around until the door lines up with the step.

b. Type C–3 and C–5 instrument flying trainers.—(1) *Unlocking.*—Two separate devices are provided with which to lock the C–3 and C–5 instrument flying trainers in a level position when they are not in use. One system consists of two lock straps primarily used for making adjustments on the trainer. The other system consists of a hydraulic jack which pulls the fuselage to a level position and holds it there. When the lock straps are being used, the hydraulic system should be released. When the hydraulic system is being used, the lock straps are swung aside against their stops. The hydraulic device can be operated either by the student sitting in the trainer cockpit or by the instructor standing outside. To release the fuselage ready for flight, *partially* open the valve located immediately below the leveling jack handle.

(2) *Locking.*—The trainer ignition switch may be turned on or off before or after locking or unlocking the trainer with the hydraulic leveler. However, if the trainer is still running while being leveled, it should be flown to nearly level position before using the hydraulic jack. To lock, close the valve below the hydraulic handle and pump the handle.

41. Use of phone system.—The instructor should bear in mind that nearly all of the student's attention is occupied with trying to keep the instruments reading as they should. It is therefore necessary to speak much more clearly than in ordinary conversation. The rate of speech should be about 25 percent slower than normal and full value given to each syllable. The student should be instructed to raise his voice slightly and direct it toward the microphone.

42. Training procedure.—*a.* Feel and stability are purposely entirely lacking in the trainer, and the student will be forced to learn to fly entirely by instruments. No attempts should be made to rush a student through in any given number of hours. Perfection should be the only goal. Ability to fly on instruments should be built as a

carpenter builds a house, the early stages of instrument flying practice laying a foundation for a structure which will be only as strong as its foundation.

b. To pilots, some of the maneuvers given in the following exercises may appear elementary and unnecessary, and they will want to skip them and get on to the more interesting radio work. The instructor should not allow this and should never assume knowledge on the part of the student, just as in navigation—radio or other—the student should never assume but prove. The best place for the instructor to start being thorough is with the first lesson. The student should be required to prove his understanding of each maneuver by explaining back to the instructor what he is going to do. If the student has previously acquired the ability to execute the apparently simple elementary maneuvers, he will not be delayed long by having to demonstrate his ability. He can progress rapidly until he reaches an exercise he cannot perform satisfactorily. If a weakness in the student's ability is discovered and corrected in these early exercises, he may sometime have occasion to thank his instructor for his thoroughness.

SECTION II

EXERCISES

43. The 1-2-3 system of instrument flying.—*a.* The 1-2-3 system applies only to the rate instruments which will be described

and refers first of all to the order in which the instruments are to be read, that is—

(1) Turn indicator.
(2) Ball bank indicator.
(3) Air speed indicator.

The readings of all these instruments can be checked almost at a single glance. It will be found that in straight and level flight in still air the turn indicator, ball bank indicator, and climb indicator will all be centered, and the air speed indicator will show cruising speed.

b. The 1–2–3 system also refers to the order in which the controls of the airplane are to be operated in order to make a turn, a glide, a climb, or any other maneuvers, or to recover to straight and level flight from any position. The relation between the instruments and the controls may be tabulated as follows:

(1) Turn indicator controlled by the rudder.
(2) Ball bank indicator controlled by the ailerons.
(3) Air speed indicator controlled by the elevators.

The 1–2–3 system is based upon this association of each instrument with its corresponding control.

c. To maintain or to return to straight and level flight, the application of the 1–2–3 system is as follows:

(1) Center the turn indicator with rudder only.
(2) Center the ball bank indicator with ailerons only.
(3) Control the air speed indicator with elevators only.

This sequence of operations is very important, but it is equally important to consider that number 1 and number 2 are to be very closely coordinated, and that number 3 is to be carried out almost at the same time. The pilot must bear in mind that the bank indicator should *always* be kept centered or slightly on the high side during a turn, *never* on the low side, either in a turn or in straight flight, to assure the correct lateral position of the airplane.

d. With a full understanding of the cause and effect relations between the controls and the instruments, and with suitable practice in the sequence of operations as outlined above, the pilot should have no difficulty in applying the 1–2–3 system. It will be, in fact, almost as simple as it sounds—"one, two, three."

e. The pilot will soon learn to follow through the 1–2–3 system just as the driver of an automobile in starting or stopping or in turning a corner does several different things each in proper sequence. The pilot will read each instrument and operate the corresponding control, each at the right time, without stopping to think what to do next.

f. The 1-2-3 system has the advantage of being both simple and definite. It definitely associates each instrument with its proper control. It is understandable, easy to remember, and easy to apply, and it applies equally well for any desired maneuver of the airplane.

44. Familiarization with trainer and instruments (exercise No. 1).—*a.* Have the student take his place in the trainer and explain thoroughly the 1-2-3 system of instrument flying. Point out to him the various instruments and explain their functions and how they are controlled. The student may be a pilot who has hundreds of hours of contact flying, but this does not prove that he knows anything about instrument flying. Do not assume that he knows anything about it. Remember, he does not know *all* about it or he would not be in your classroom. Since you do not know the points on which he is weak, it is necessary to cover the subject completely. If the student is inclined to say, "Yes, yes, I know all about that," and is impatient to get on, ask him to explain the 1-2-3 method and control of the instruments to you. If he does know, no time need be wasted; but if he has misconceptions as to the proper procedure, you can set him straight so he will not waste even more time later in the course.

b. When the foregoing procedure has been thoroughly covered, unlock the trainer as previously described. Five to ten minutes may be spent with the hood up if the student has never been in a trainer. It is a waste of time for the student to spend a half hour to an hour getting the feel of the machine. Remember that he is starting to learn instrument flying where feel must be ignored, not used. Any mechanical tricks the student might learn about the trainer with the hood open will only handicap him later. He will waste time trying to hold the trainer in the proper attitude by means of these tricks and by feel, and will not make real progress on instruments until he has unlearned these shortcuts and finally started to read the instruments. Before placing the student in the trainer, the instructor should turn on the radio in the trainer desk so that it will be warmed up and ready. The student should be asked to put on the earphones and the use of the microphone should be explained to him.

c. After unlocking the trainer, the instructor should immediately take his place at the desk and microphone and continue the instruction from there. Have the student apply a little rudder and note the reaction of the turn indicator needle; ask him to bank in one direction and then the other and observe the ball bank indicator; have him move the nose up and down with the elevators and note the reaction of the air speed indicator; and have him open and close the throttle and check the reaction on the air speed, tachometer, and ver-

tical speed indicator. Not more than 10 minutes should be spent during this period with the hood open. The student should then be asked to close the hood. With the hood closed, again ask the student to go through the maneuvers just completed; outlining the process one step at a time, have him note that with the hood down the same controls have the same effect on the instruments that they did with the hood open. When the student has a clear understanding of how the 1-2-3 system at least ought to be done, and demonstrates that he understands what controls affect which instruments, he is ready for exercise number 2.

45. Straight course (exercise No. 2).—*a*. This exercise is designed to acquaint the student with the number one instrument of instrument flying, the turn (and bank) indicator. During its practice the directional gyro must be caged. Before starting the exercise, no effort should be made to attain any given altitude or in fact any altitude at all. The air speed indicator likewise receives no attention other than enough coaching to keep the student out of a spin. The problem at this stage is simply to learn to control the turn indicator. A certain amount of attention will, however, have to be given the ball. Explain to the student that if the ball gets off to one side the turn indicator needle will have a very pronounced tendency to get off on the same side also. (Naturally, the ball on one side indicates that a wing is low and that the craft will shortly start turning in that direction just as an airplane does in actual flight. But do not make the mistake of talking too much to the student about the attitude of parts of the craft; rather, confine your comments to the instruments themselves.)

b. Explain thoroughly why it is necessary to average the swings of the turn indicator needle. Point out that if the needle is observed to be off to one side it is definitely essential that it be offset an equal amount, for an estimated equal period of time, on the other side before centering it, in order to return to the desired heading.

c. The student should be frequently cautioned against becoming tense, and should be requested to relax by momentarily letting go of the controls and by moving around in the seat. He should also be warned against becoming hypnotized by any one of the instruments to the point that he can neither relax nor look over the rest of the instrument panel. Tendencies toward tenseness and overconcentration on some one instrument will be found in nearly every student, and the instructor must be constantly on the alert if he would have his students make normal progress. In connection with this it is not advisable to have the student spend more than 30 minutes under the hood at a time.

d. The foregoing straight course exercise should be continued until the student can hold a straight course within + or − 10° over a 5-minute period.

46. Straight and level flight (exercise No. 3).—*a.* In starting this exercise the student should be requested to open the throttle wide and maintain cruising air speed. A climb will result. The student should maintain the same air speed and hold the same heading until an altitude of 1,000 feet is reached. When this altitude is reached the student should be instructed to throttle back sufficiently just to hold the altitude, still maintaining cruising air speed and holding his heading.

b. Since it is the purpose of the early (and subsequent) exercises to form mental and physical habits in the instinctive or subconscious control of instruments, the instructor must remember to follow the 1–2–3 order in giving commands, especially in getting the student out of difficulties; for example, "Stop the turn with the rudder only; center the ball with the ailerons only; and check the air speed with the elevators only"; etc. Even if only one instrument has moved away from its desired indication, start at the beginning and go through the 1–2–3 order, emphasizing slightly the instrument in question.

c. As the student throttles back to remain at the assigned 1,000-foot level, he must move the elevator control forward slightly, hold it there for a few seconds, and then return it to neutral in order to prevent the air speed from decreasing. In the process, the vertical speed indicator should be brought to zero. It is very important that it be drilled into the student to control the vertical speed with the *throttle* only and the air speed with the *elevators* only; and that he must *not* try to control the vertical speed with the elevators. The air speed must be held at cruising with the elevators and the trend of the altimeter noted. If altitude is being lost, more power must be applied; if gaining altitude, slightly reduce the power. *A correction must not be applied either to throttle or elevators because of the altimeter or vertical speed indicator without first checking the air speed.* If there is doubt as to whether the student is following this rule, the vertical speed indicator should be covered until the student has demonstrated his ability to control the air speed.

d. The majority of students encounter considerable difficulty in controlling the air speed. The instructor must keep an attentive eye on the trainer and note any tendency of the student to overcontrol and to let the air speed oscillate. When such difficulty is present (and it usually is), the student should be instructed to make smaller corrections and to allow them time to take effect. The instructor should explain the so-called lag in the air speed indicator; make clear that

the lag is nearly all due to the comparatively slow rate of acceleration and deceleration of the airplane itself; that after a momentary correction has been applied which has slightly changed the attitude of the ship, it will take a few seconds for the craft to pick up or lose enough speed to reflect in the air speed indicator. For example, if a ship capable of 200 miles per hour were being climbed, full throttle, at 100 miles per hour and the stick suddenly pushed forward enough to put the airplane in a level flight position, it is to be expected that it will take several seconds for the ship to reach its full speed of 200 miles per hour.

e. Bearing the above in mind it naturally follows that if the stick had been held forward until the air speed actually reached the 200 mark, the ship would have continued nosing down until by the time the indicator showed the 200 the ship would have been in a steep or vertical dive. It is therefore necessary to remove the correction on the elevators long before the air speed has reached the desired amount. This is known as "leading" the air speed indicator. The amount that it must be led will depend upon the speed at the moment and the rate at which the pointer is moving. The faster the pointer is moving the more it must be led. For example, in recovering from a stall or near stall, the correction to the elevators must be removed almost as soon as the air speed starts to increase, in order that the nose not be allowed to get too low.

f. Since a student's future success as an instrument pilot, and indeed his very life, will depend on his ability to control the turn and bank indicator and the air speed indicator, it is vitally necessary that the preceding exercise be continued until he has a complete understanding of their control. Minimum standards of proficiency on this exercise should be the ability to hold the heading within + or − 5° for 5 minutes, air speed constantly within + or − 10 miles per hour of cruising, and altitude definitely within + or − 100 feet. It should be borne in mind that these are minimum standards and neither the student nor the instructor should be satisfied but should strive for better results.

47. Standard rate turns (exercise No. 4).—*a.* A turn of 180° per minute (3° per second) or a one needle-width deflection, either right or left, on the turn indicator is considered a standard turn. When the command to make a standard turn is given by the instructor, the student should take up this rate. In order to make a smooth standard turn, a great deal of coordination of the controls is necessary in entering, during, and in the recovery to straight and level. The turn should be started by use of the rudder and followed almost simultaneously by the ailerons and then the elevators to keep the air speed constant.

Lead with the rudder, follow with the ailerons as necessary to control the ball, and maintain the air speed with the elevators. Once the proper turn is set, it is not difficult to maintain a constant rate, but it is necessary constantly to be rechecking the needle, the ball, and the air speed to keep the correct attitude.

b. In the recovery it is equally important for the controls to be coordinated for a good smooth recovery. By knowing, applying, and practicing the 1–2–3 system this will soon become a very simple operation. After giving the command for the student to recover to straight and level flight, the instructor should frequently use the following terms and expressions until they become habit to the student: "Stop the turn with the rudder only; center the ball with the ailerons only; check the air speed with elevators only; correct altitude with the throttle only."

c. During the practice of standard rate turns, the student will usually encounter difficulty in holding the turn steady due to the ball getting off center. The chain of events that usually occurs is as follows: the ball will get slightly on the low side (banked too much) causing the turn needle to move too far from center (rate of turn speeded up). The student will correct the needle without proper coordination, and the ball will then be still farther on the low side. The student then usually rolls the ball to center again without proper coordination of the rudder and the turn stops. Stopping and starting the turn in a series of jerks will result. To remedy the trouble, the student must be taught how to "cross controls" when he wishes to correct the ball without disturbing the turn needle, or correct the needle without disturbing the ball.

d. The following subexercise will usually correct the student's difficulty and give him a clear understanding of the trouble; have him hold the turn indicator needle centered and slowly roll the ball to the left just barely outside the lubber lines. Have him note that the turn needle tries to follow the ball and that to keep the needle centered it is necessary to give right rudder. Then have him roll the ball to the right of the lubber lines and note that to keep the turn needle centered he must slowly remove the right rudder previously applied and gradually apply left rudder. After a few minutes spent in this practice, have the student start a standard turn and during the turn roll the ball slowly from side to side as just outlined, meanwhile maintaining the turn needle at the desired mark.

e. In general, during the practice of all turns the ball should be kept just slightly on the high side (not more than $\frac{1}{16}$ inch outside the lubber line). The ideal place to maintain the position of the

ball is in the exact center. However, since the student instrument pilot does not have perfect control, and the ball must not be permitted on the low side (because of turn tightening and the resulting diving spiral), he should be definitely required to carry it slightly on the high side.

f. Standard turns of 360°, 270°, 180°, and 90° should be practiced. These turns should be made with the turn indicator and clock, and the instructor should check their accuracy with a stop watch. The student should not pass on to the next exercise until these turns can be made with not more than 10° of error for each 90° of turn, the air speed held within + or − 10 miles per hour, and the altitude maintained within + or − 100 feet of that assigned.

48. Standard rate turns to compass headings (exercise No. 5).—*a.* It is very essential for the student to be thoroughly familiar with the compass rose and to be able to interpret compass headings in degrees very quickly. This knowledge and ability will be indispensable in problems to follow.

b. In making turns to compass headings two things will be practiced, the turn and the use of the compass. The proficiency of the student will be based on his ability to make a smooth turn of the least magnitude to an assigned heading. For instance, if a student flying on a heading of 90° were directed to make a standard turn to the heading of 180°, he would make his turn to the right. If he were to make his turn to the left, he would be covering three times as much distance as the turn to the right would require.

c. These turns should be made by the count without using the clock. If the sweep hand on the clock is not the type which can be stopped it should be covered up. Amounts of turn should range from as little as 10° to as much as 360°. The student should count out loud so the instructor can check and correct his cadence. Trying to count seconds as "one . . . two . . . three," etc., is not usually successful, because whenever the student is diverted momentarily by one of the instruments his cadence will speed up or slow down. It has been found that the cadence can be maintained much more accurately if the space between counts is filled by some convenient word of the right length and rhythm; for example, "uh thousand and one uh thousand and two uh thousand and three," etc. The accuracy of cadence can be further increased by counting in units of ten; 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30, etc., still using the "thousand and." To aid in remembering how many units of ten have been counted, the student should raise one finger on the wheel or stick for each unit.

d. The value of this exercise is sometimes questioned by students. The instructor should remember that it has several purposes, only one of which is merely to make turns by the count. For one thing, it is the first exercise which gives the student a little practice in thinking—and remembering—while still controlling the instruments.

e. The directional gyro should be caged and the accuracy of the turns checked by the instructor with a stop watch and the tags on the trainer base. The minimum of proficiency should be an error of not more than 10° for each 90° of turn, the air speed held within + or − 10 miles per hour, and the altitude within + or − 100 feet.

49. Coordination of throttle and elevators (gyro caged) (exercise No. 6).—*a.* Considerable time is usually lost by the student when he attempts climbs and glides because of his lack of ability to coordinate the throttle and elevators; when he tries to correct the vertical speed with the throttle, the air speed changes; and when he tries to correct the speed, the vertical speed gets out of bounds. Much of this trouble can be smoothed out and time saved later on by the following exercise: starting at cruising speed, have the student slow down to gliding speed, still maintaining his heading and holding a constant altitude. The gyro should be caged and the horizon covered. The process is to lose the air speed with the elevators and prevent a climb with the throttle. The student should press back slowly on the elevators and at the same time gradually close the throttle partially as necessary to maintain the vertical speed indicator at zero. When the student has the instruments steadied down at gliding speed, have him return to cruising speed. The air speed must be regained with the elevators, meanwhile opening the throttle as necessary to prevent loss of altitude.

b. The exercise should be continued until the student can perform it smartly, smoothly, and within the following limits: heading within + or −5°; altitude within + or −50 feet. During this exercise (as well as several others), if the trainer is not equipped with remote indicating instruments, the instructor will be of much more help to the student if he will obtain and use an extension cord for the desk mike and earphones, and stand outside the peephole in the trainer and watch the instrument reactions.

50. Straight climbs and glides (exercise No. 7).—Straight climbing and gliding should be practiced at cruising air speed (at slow speed in a later exercise), and at vertical speeds of 400 and 500 fpm (feet per minute); starting at, say, 1,000 feet altitude, the student should be asked to climb at 500 fpm to a new altitude of 2,000 feet. Upon reaching the assigned altitude the student should level off and

maintain that altitude + or − 50 feet. Then have him descend at 500 fpm back to 1,000 feet altitude. When a fair degree of proficiency has been acquired, the changes in altitude should be reduced to 500 feet so that the student is given more practice in going into and recovering from climbs and glides, thus obtaining additional practice in throttle and elevator coordination and also to get more repetitions of the exercise into a half-hour session. During this exercise the instructor should be particularly on guard against the student becoming careless with the air speed, remembering the ever-present temptation on the part of all beginners to attempt to control the vertical speed with the elevators. Minimum proficiency: air speed + or − 10 miles per hour; heading within + or − 5°; vertical speed within + or − 100 feet of desired mark.

51. Climbs and glides while turning (gyro caged) (exercise No. 8).—Climb or glide to an altitude predetermined by the instructor. For example, from an altitude of 1,000 feet, do a standard rate (3° per second) climbing turn to an altitude of 2,000 feet at 500 fpm. Climbing should be started at the same instant the turn is started, and the turn and climb both smartly stopped on reaching the 2,000-foot mark. If executed correctly the maneuver will be completed in exactly 2 minutes, and the recorder will show that 360° of turn were made. A simple analysis will inform the instructor what errors were made by the student. For example, if the maneuver occupied 2 minutes and 15 seconds and the recorder indicated that 405° of turn were made, it is obvious that the rate of turn was correct (3° per second), but the student had been slow getting the rate of climb to the desired figure or had not held it at the proper indication. In short, if the vertical speed is maintained at the proper indication, the maneuver takes 2 minutes. If the turn indicator is controlled properly, the recorder will show 3° of turn for each second the student spent executing the maneuver.

52. Climbing and gliding turns to predetermined altitudes and headings (using clock, gyro caged) (exercise No. 9).—*a*. The following exercise is designed to give the student practice in doing several things at once. It requires him to remember a new heading and how long it will take to reach it and to remember his new assigned altitude; he must stop one maneuver while continuing another (and he cannot be sure which will occur first until the indications are reached); and he must keep close track of several instruments. During each problem the instructor should time each turn and change in altitude with the stop watch.

b. With the student flying level at, say, 1,000 feet, ask him to change altitude to 1,500 feet and at the same time do a right turn of 170°. The climb and the turn must be started simultaneously. When he reaches the new heading the turn must be stopped and that heading held, and he is to level off when he reaches the 1,500-foot altitude. A climbing turn of 200° to the left should then be made, stopping the climb at an altitude of 2,000 feet. If the maneuvers are well-executed in making the 170° turn, the new heading will be reached only a few seconds before the new altitude; in the 200° turn the new altitude will be reached a few seconds before the new heading. If the exercise is not accurately done the student cannot tell which goal (the new heading or the new altitude) will be reached first, so consequently must keep close track of both the turn indicator and the altimeter as well as the other flight instruments. The exercise should be accomplished within the following limits: air speed within + or − 10 miles per hour; rate of turn within + or − 10° for each 90° of turn. On reaching the new altitude it should be held within 50 feet and the new heading, when reached, within + or − 5°.

53. Practice in rough air (exercise No. 10).—Briefly review exercises Nos. 6, 7, 8, and 9 with the rough air on. Air speed limits should be reduced to + or − 5 miles per hour. Other limits remain as before.

54. Slow flight practice (exercise No. 11).—Repeat exercises Nos. 8 and 9 at gliding air speed (without rough air).

55. Emergency pull-up (exercise No. 12).—This exercise is one which has a very practical application when the instrument pilot some day gets down to his minimum altitude and finds that he still has not broken out of the overcast, and finds it necessary to go around again or proceed to his alternate station. Require the student to attain an altitude of, say, 2,000 feet and slow flight (gliding) air speed. Then instruct him as follows: still maintaining a constant air speed throughout the maneuver, descend at 500 fpm to an altitude of 1,500 feet. Upon reaching this exact altitude ease the throttle fully open and climb back to 2,000 feet. Upon reaching 2,000 feet, level off and hold this altitude, still maintaining slow flight air speed. When a fair degree of proficiency has been acquired, require the student to start a turn of 45° at the time he reaches the minimum altitude and starts back up. Proficiency: air speed + or − 5 miles per hour; heading held within 5°; vertical speed within + or − 100 feet per minute.

56. Stalls (without spinning) (exercise No. 13).—*a.* This exercise is designed to acquaint the student with the appearance of the instruments at the approach of a stall, and to drill him in instinctively ap-

plying the proper correction and leading the instruments back to normal flight indications.

b. Request the student to reduce the air speed slowly by nosing up. Continue to reduce air speed gradually and note the action of the vertical speed. In trainers that cruise at 160 mph with the pointer in the 3 o'clock position, the vertical speed indicator will start to fall back at around 90 mph. In properly adjusted trainers the vertical speed will fall back to the vicinity of zero before the trainer starts to spin. (The instructor should be acquainted with the performance of his particular trainer.) The air speed at which "mush" is indicated on the vertical speed should be noted and the speed then recovered to normal. Straight flight should be maintained with the turn and bank indicator throughout the maneuver.

c. The exercise should be repeated several times, reducing the air speed each time until the vertical speed falls almost to the point where a spin will occur. During the exercise the ball should be kept centered and the heading held within + or − 5°.

57. Spins (exercise No. 14).—*a*. The chief value of the spin in the trainer is to aid in further immunizing the student to vertigo and to drill him in correctly reading and controlling the instruments regardless of any physical sensations he may experience.

b. Spins should be entered smoothly as in an airplane. Do not allow the student to jerk the stick or wheel back suddenly as if he were attempting a snap roll. Rather, require him to reduce the air speed slowly, noting all the instrument indications as he does so, until the trainer starts to spin. When a spin is started ask the student to apply full rudder in the direction of the spin and to pull the stick or wheel back. The nose of the trainer remains high, of course. The student, however, cannot see the attitude, and if he had never watched anyone else spin the trainer it is is doubtful that he would be aware of the nose high position. The instruments indicate properly (for a flat spin, as the air speed continues to fall back), and since the recovery must be made by instrument the attitude is unimportant.

c. The angular movement possible in the trainer is, of course, limited. Therefore, the trainer will reach a terminal velocity and limit of nose down movement when down against the front stop. In teaching spins in the trainer, it is very important that the student not be permitted to nose down too far and rest against the front stop when recovering. If he is permitted to form such a habit in the trainer, when he attempts recovery from a spin in an airplane, he will push the controls forward too far or hold them forward too long and put the ship on its back. Permitting the student to build up excess speed should be carefully guarded against.

58. Turns to gyro headings (exercise No. 15).—*a.* Inasmuch as most of the preceding exercises have been performed without using the directional gyro, the student may not be acquainted with the use of the instrument. Practice in setting it to the magnetic heading (making use of the deviation card) and in making turns by it should be fully understood by the student. Be sure the student understands that he cannot obtain an accurate reading from the compass unless the craft is flying straight and level and at a constant air speed.

b. Standard rate turns should then be practiced, stopping the turns on predetermined, exact gyro headings. The turns should range from as much as 30° to as little as 5°. For the purpose of this exercise there is no point in wasting time making turns of more than 30°. By keeping the length of the turn short, a much greater amount of practice will be obtained in stopping the turn on specified headings.

c. Practice should be continued until the student can stop the turn and keep it stopped exactly on any specified heading. During the exercise the instructor should time the turns with the stop watch and thus check the accuracy of the student's handling of the turn indicator needle. The air speed should be held within + or − 5 miles per hour.

59. Use of artificial horizon (exercise No. 16).—This instrument has been purposely left out of the exercise up to this point to insure that the student is thoroughly trained on the rate group. Intelligently used, however, the horizon is a valuable aid in reducing fatigue and in doing more accurate instrument flying. Its limitations should always be borne in mind and a constant cross check be maintained on the other instruments. Its chief value lies in the fact that as long as it is functioning correctly it has no lag, and indicates the attitude of the airplane relative to the horizontal with practically no need for interpretation on the part of the pilot. This is a very considerable help when making low approaches on instruments to an airport. The air speed and vertical speed indications can be considerably smoothed out with the aid of the horizon. Require the student to practice changing from cruising speed to slow speed and vice versa by reference chiefly to the horizon. While at cruising speed, have student note the position of the miniature airplane relative to the horizon bar, then have him reduce speed to gliding speed and note the position of the airplane and bar. Having noted the two positions, have him change the attitude so as to put the airplane and bar in their cruising position, maintaining altitude with the throttle as usual, and note that the air speed returns to cruising. Then nose up until the little airplane and bar are in their position for gliding speed, meanwhile maintaining level flight (constant altitude) with the throttle, and note that the speed smoothly

reduces to gliding speed. Practice should continue until the exercise can be executed smartly, meanwhile holding the altitude within + or − 100 feet and the heading within 5°.

60. U-track (exercise No. 17).—*a.* A signal should be agreed upon so that when the student is ready to start the problem the instructor will start the recorder. As the student signals that he is ready he should start the sweep hand of the clock. This course (north) is held for 1 minute. (See track ①, fig. 19.) At the end of this period, the clock should be stopped, cleared, and started over; and at the same time the 90° turn to the right should be started. The turns may be stopped by the gyro, but the pattern will be spoiled if the turn indicator is not properly controlled throughout the maneuver. The clock should be stopped and started over again at the end of each straight run and each turn.

b. The problem should be started at an altitude of 2,000 feet. After coming out of the first turn onto the east heading, the student should climb to an altitude of 2,500 feet. At the start of the turn from the fourth leg (north-bound) onto the west leg, a descent of 500 fpm should be started. Continue the glide to an altitude of 1,500 feet. This altitude should be held throughout the rest of the problem. On the last leg, prior to going into the last turn, the air speed should be reduced to gliding speed. As the final turn is completed, the student should signal the instructor, who will shut off the recorder. The starting point and finishing point should be within 1/8 inch of each other with slow recorder motors. The altitude should be held within + or − 50 feet, except when changing to a different level as previously prescribed, and the air speed maintained within + or − 5 miles per hour.

c. The U-track (track ①, fig. 19) as previously described is for use with the constant speed recorder of the type C-2 and C-4 instrument flying trainers which do not have a wind drift device.

d. Type C-3 and C-5 instrument flying trainers are equipped with a variable speed recorder which faithfully reproduces ground speed. Consequently, the length of time some of the U-track headings are held must be revised to fit this condition. As will be noted by reference to track ②, figure 19, the west heading is held for 2 minutes 5 seconds instead of 2 minutes 16 seconds. It will also be noted that the latter half of the final south leg must be held for 60 seconds instead of the previous 45 seconds to allow for the slower tracking speed which results from slowing down from cruising to slow flight speed. The wind velocity and wind direction dials must be set at zero during this problem.

e. Tolerances for the completed U-track should be the same regardless of which type of trainer is used. The objective of the U-track is to test how well the student has mastered the previous maneuvers. If he cannot accomplish it properly, his failure will point out the exercise on which he is weak. If he succeeds, he is ready to advance to radio navigation practice.

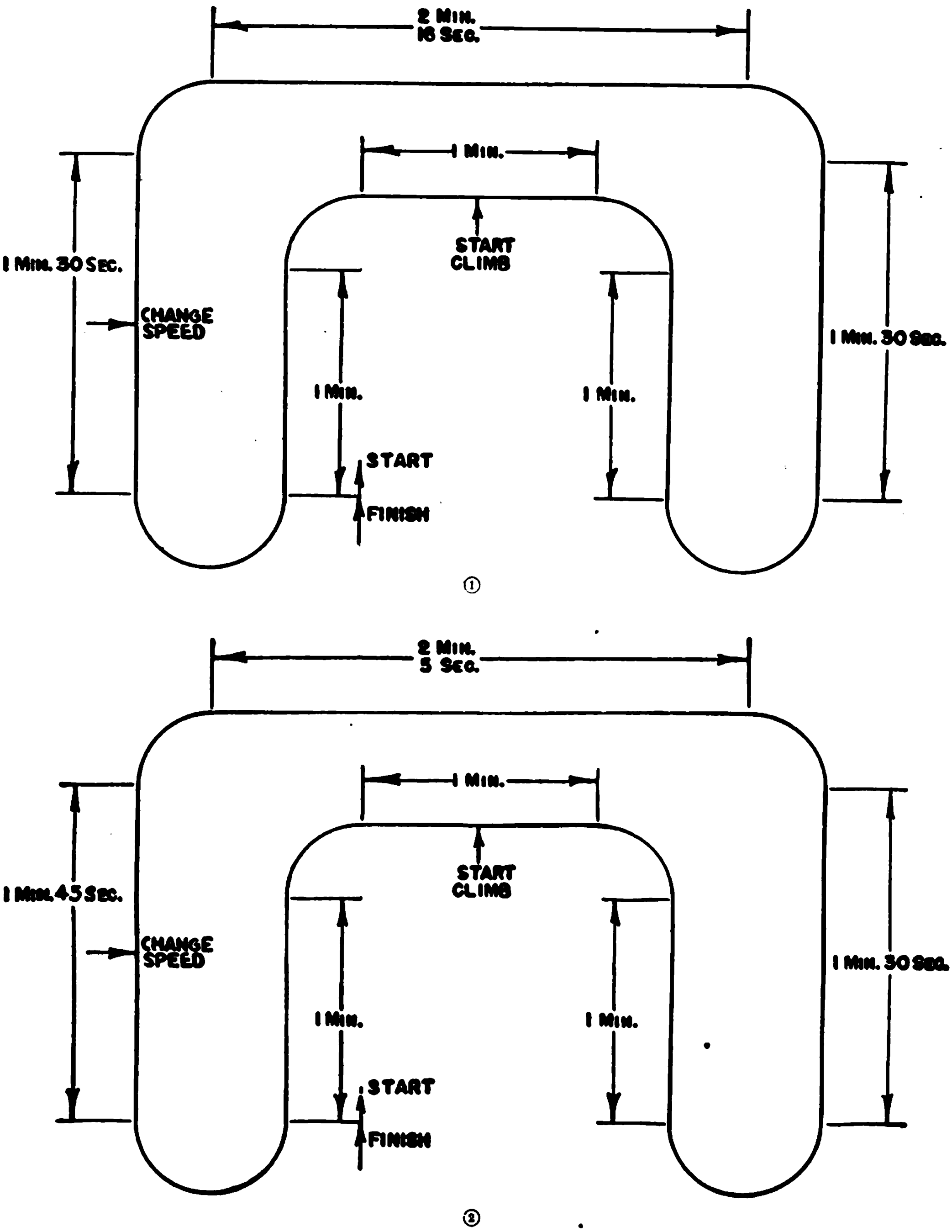


FIGURE 19.—U-track, instrument flying trainer.

61. Training procedure.—*a.* Due to the fact that in line squalls or other violent atmospheric disturbances it is possible for an airplane to be tossed about sufficiently to upset the artificial horizon and directional gyro, necessitating control of the plane by the rate instruments, the majority of instructors consider it advisable to complete most of the instrument course with the horizon covered up and the gyro caged. Since the horizon and gyro are very valuable adjuncts to instrument flight, comprehensive instruction in their intelligent use should, however, be a part of the course.

b. Located under the lower right rear of the trainer fuselage is an icing valve. This valve enables the instructor gradually to shut off the vacuum to the air speed indicator and simulate icing up of pitot. At intervals during the course, without warning to the student, this feature should be used. The student is thus taught to cross-check his instruments and compare them with one another. A pitot tube heater switch is located near the right-hand lower corner of the instrument panel of the type C-3 instrument flying trainer. As soon as a student notices the malfunctioning of the air speed indicator, he should turn on the pitot tube heater. The instructor should thereupon gradually open up the icing valve to normal.

c. At times, during orientation or cross country practice in the later part of the course of instruction, the gyro instruments (directional gyro, turn and bank, and artificial horizon) should be rendered inoperative without advance notice to the student, simulating failure of these instruments. A valve which shuts off the vacuum to the directional gyro and the turn and bank indicator is located under the skirt on the right-hand side of late models of the type C-3 trainer. Opening this valve restores these instruments to their normal operation. (This feature will be added at a later date to trainers now in service.)

CHAPTER 2

RADIO AIDS TO NAVIGATION

SECTION I

RADIO RANGE INSTALLATIONS

62. General.—The student who has mastered the system of instrument flying covered in the preceding section is now able to control the attitude of an aircraft by reference to instruments alone. He is able to fly his aircraft into conditions of reduced visibility and continue his flight by reliance upon methods of dead reckoning. He will be able to maintain a reasonably accurate course, provided he knows the direction of the wind at his flight level. Indeed, under many conditions, he may have to carry on without the help of radio directional aids. If the pilot proceeding on an instrument flight arrives in contact weather conditions before his fuel supply is exhausted he can then continue to his destination by methods of pilotage. However, it is obvious that the above is an emergency procedure and that regularly scheduled flights could not be carried out by such methods. A comprehensive system of radio aids to navigation comprising the civil airways system of the United States and of the Dominion of Canada has been installed to provide navigation facilities available under instrument flight conditions. The principal component of the system is the radio range station—a radio station emitting aural signals by means of which directions may be established.

63. Patterns.—*a.* Begin by comparing a radio range which controls the intensity of its signals in certain directions with a conven-

tional broadcast station which normally radiates its energy with substantially the same intensity in every direction. Figure 20 illustrates the circular shape of the pattern covering the area over which a broadcast station would be heard with an ordinary receiver. Signals are strong near the transmitter and grow weaker gradually as they spread out in all directions until they fade out entirely. The radius of this circular area could be considered greater or less as the receiver volume is advanced or retarded or the transmitter power is increased or decreased.

b. The shape of the pattern in which signals are audible can be controlled to some extent by use of specially designed, transmitting antennas, one type of which is the loop illustrated in figure 21.

(1) Comparing the pattern of the loop with the pattern of the broadcast antenna, it will be found that radiation from the loop is suppressed in both directions at right angles to the loop, and maximum radiation is obtained in the direction in line with it. The loop is represented at the center of figure 22 as it would appear if viewed from directly above. Note the directions in which it points by reference to the aircraft compass rose drawn around the figure. For identification purposes the signals radiated by this loop are broken up into a succession of dots and dashes corresponding to the letter A (dot dash) and so represented by blocking in the areas covered by the signals. Figure 23 represents the area which would be covered by another identical loop at the same location but rotated 90° (at right angles) and transmitting a succession of letter N's (dash dot).

(2) Two such loops radiating alternately would cover the areas shown in figure 24. It is obvious that only in the zones in which adjacent areas overlap would both the A and N signals be audible.

(3) At the landing field represented by F in figure 24, both A and N signals would be heard with exactly equal strength, resulting in a steady monotone. The same would be true at any other point on a line drawn through the center of each of the four zones of overlapping signals.

(4) An airplane taking off from the field, flying away from the transmitter and following the line along which the A and N signals continue to be received with equal strength, would start with the receiver volume near minimum. The signal strength would drop off rapidly at first, making it necessary to advance the manual volume control at frequent intervals. (Automatic volume control is unsuitable for range navigation.) As the signal became progressively weaker with distance the volume control would have to be advanced less frequently. Eventually the limit of receiver sensitivity would

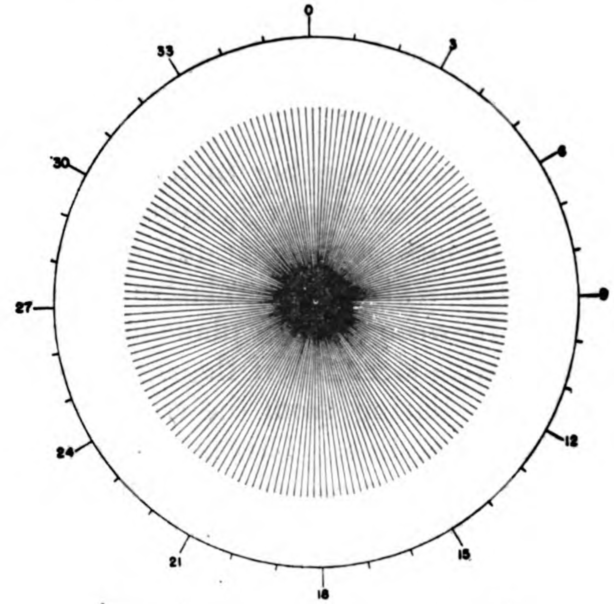


FIGURE 20.

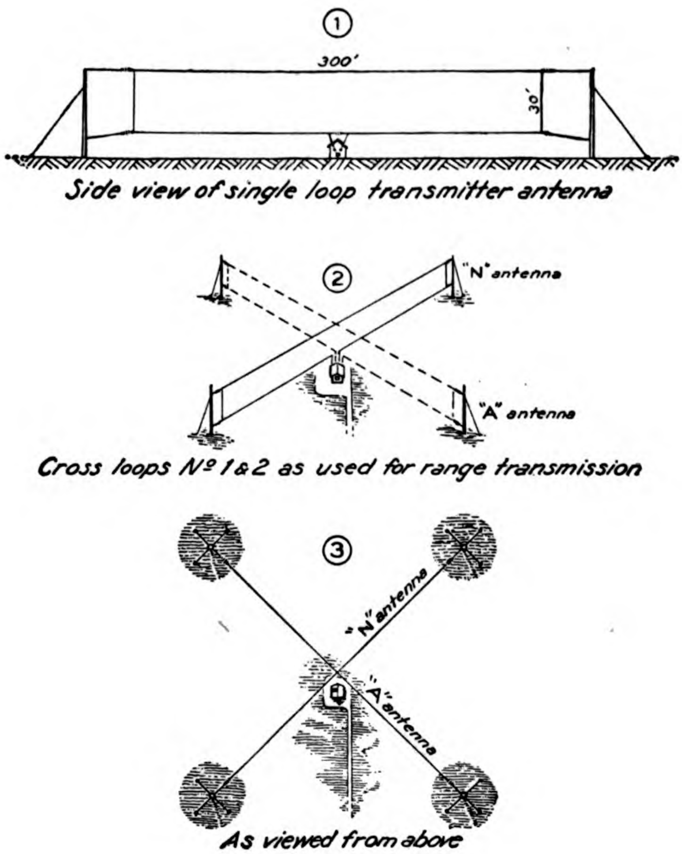
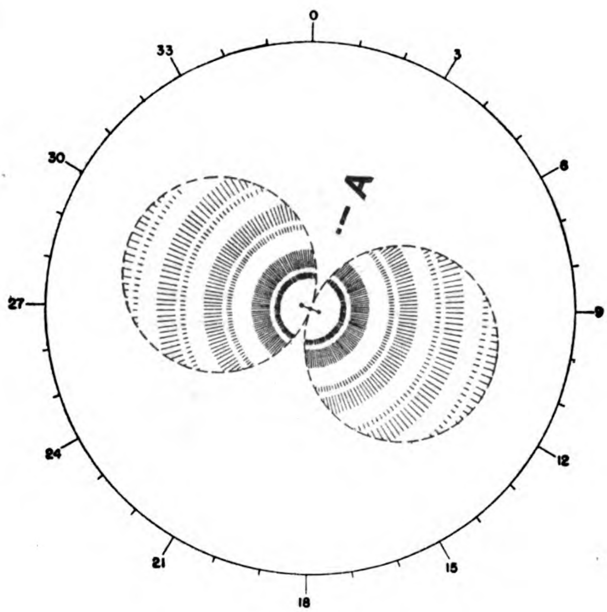


FIGURE 21.

be reached or accompanying atmospheric noises and interfering stations become louder than the desired signal. This occurs under ordinary conditions and with full-powered stations from 100 to 200 miles from the station.

(5) At this distance it is possible to fly several miles before a noticeable change in signal strength is apparent to the ear. It is likewise possible to deviate a considerable distance to either side before the ear can detect a change in relative signal strength of the N and A. The limits between which a plane may range to either side before a change in relative strength of the signals is apparent can be represented by a line radiating from the transmitter approximately 1½° each side of the center line. This is actually the way in which courses are plotted on aeronautical charts. The magnetic bearing of each course in degrees toward the station is published in radio facility charts for all stations.

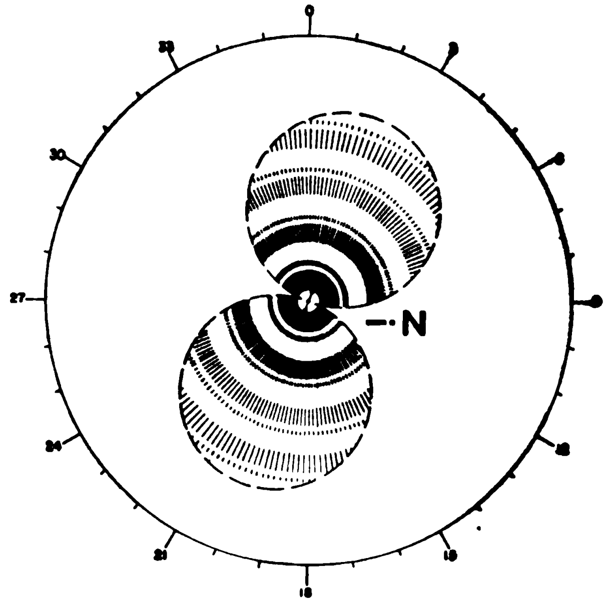


SINGLE LOOP
BEARING 110° AND 290°

FIGURE 22.

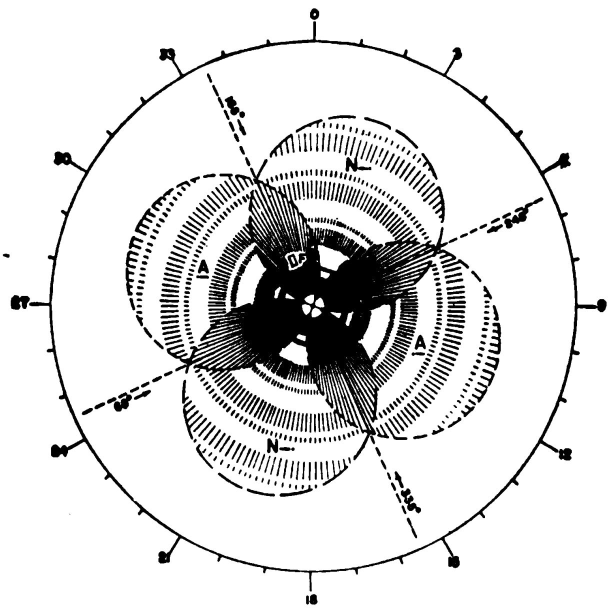
c. It is now obvious that radio range courses are merely narrow wedge-shaped zones in which two signals of equal strength are received as a monotone. The degree of accuracy with which the ear judges relative signal strength (particularly station identification signals) determines the accuracy with which the pilot can fly a radio range course.

d. Like the entertainment broadcast band, the aeronautical radio frequency spectrum (200–400 kc) must accommodate a great number



SINGLE LOOP
BEARING 20° AND 200°

FIGURE 23.



LOOPS A AND N COMBINED

FIGURE 24.

of stations, and some interference is unavoidable. To eliminate all danger of mistaken identity, each station is assigned an individual two-letter identification. Approximately every half minute the course signals are interrupted, and the station identification signals are transmitted twice in code, one from each loop, whereupon the course signals are resumed. For instance, the pilot wishes to tune in the radio range at Blank City. He knows that the radio frequency is 260 kc and that the identification signals are BU (— . . . . . —). He turns the radio dial to 260 and receives a signal. He waits until the station identification signals are transmitted and reads them as BU. This has definitely established the fact that he is listening to the Blank City range.

e. When a pilot is flying away from a range, the farther he progresses the less accurately does he know his position, but if he follows any of the four courses toward the station he will be led to a definite point. That point can be identified aurally by what is usually termed the cone of silence. It is an area normally directly above the transmitting antennas in which all signals fade out when the airplane passes directly through it. It should not be confused with momentary fade-out of signals sometimes found along airways, resulting from other causes, and should be definitely checked by noting whether the zone signal on the right has reversed. Unless the receiver volume is kept at a minimum value and the airplane is exactly on-course when passing over the station, the signal will not fade out completely. The airplane receiving antenna should be as nearly vertical as possible for best results. The reasons for these precautions will be evident from a study of figure 25, which shows the normal position and shape of the cone of silence. The pilot should have a complete understanding of the inherent limitations of radio ranges before attempting to fly them during inclement weather.

64. A and N quadrants.—All radio ranges operated by agencies of the United States have the off-course signals arranged according to the following rule: A true north line through the station passes through the N quadrant. If the north on-course coincides with the true north, the N quadrant is the northwest quadrant. Canadian radio ranges transmit N in the northwest quadrant, the northwest quadrant being defined as the quadrant containing the true bearing of 315° from the station. The A quadrants are identified in the Air Corps Radio Facility Charts, carried in all military aircraft, by the black sectors of the circle drawn around each radio range station. In addition, in the case of Canadian stations included in these charts, the letter

N with the code signal — . is shown in the NW quadrant near the station.

65. Power of radio ranges.—The power used for radio range transmission varies with the different stations. A full-powered station uses more than 150 watts, a medium-powered station 50 to 150 watts, and a low-powered station less than 50 watts. Except for signal strength, little difference will be noted in these stations. In the Air Corps Radio Facility Charts, the full-powered stations are shown with their on-course signals 100 miles in length, while medium-powered and low-powered stations are shown as 50 and 25 miles, respectively.

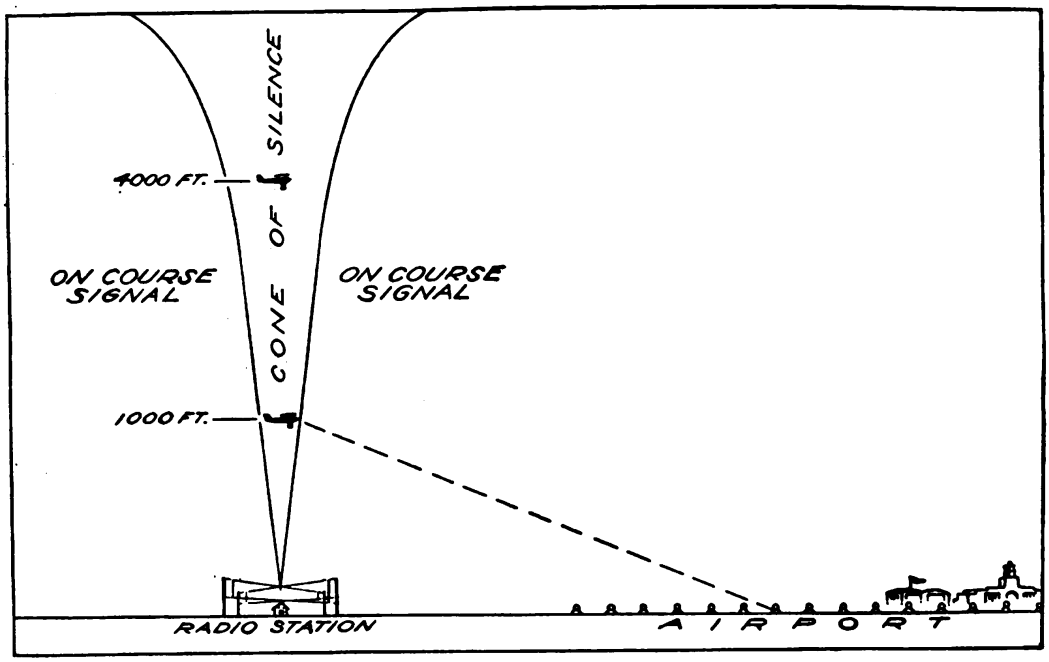


FIGURE 25.

66. Irregularities.—*a. Multiple courses.*—(1) Where multiple courses exist, they manifest themselves as on-course monotones heard in locations where the predominant signal should be either A or N. They may lead the pilot to believe he is flying on the airway when as a matter of fact he may be some miles from it.

(2) Mountains and rough terrain undoubtedly cause an interference to radio waves resulting in a very uneven distribution in the signal strength, producing multiple courses. They exist both with the loop antenna and with the RA type, and there seems to be very little difference as to the number of multiple courses or the area covered. In general, it has been found that within a distance of 10 to 15 miles from the radio range station, the multiple course effect is not sufficient to prevent the use of the range beacon. However, at distances greater

than 30 miles from the transmitter there have been many instances of 5 or 6 courses. The spread of these courses, the width of the band, may be many times that of the normal course and in some cases has been known to cover an angle of as much as 18°. The spread or the angle over which these courses exist varies with the distance from the transmitting station. For example, the radio range may have one 3° course, which may extend 10 miles from the station and then at this point may split into 2 or 3 courses covering an angle of 4° or 5°; and again may split at a distance of 30 miles from the station into a band covering 8° to 10°; and at 50 miles, courses may continue to split, covering an angle of 10° to 12°.

(3) There appears to be no continuity to the courses, inasmuch as there appeared to be a band in which courses would appear, but on crossing the course possibly a half mile closer to the station an entirely different arrangement of courses would be noticed. It may also be found that the arrangement of the courses varies widely with altitude. (See fig. 26.)

(4) When a course is directed down a valley which is bound by regularly defined mountain ranges on either side, the splitting of courses is found to be most evident. Courses seem to split up more under this condition than any other condition which has been experienced. On the other hand, if the courses are projected perpendicular to a range of mountains or several ranges of mountains which are regularly defined, a negligible amount of splitting occurs.

(5) When courses are projected across mountain ranges at an angle, it has been found that they will split at the mountain peak and continue to split, depending upon the number of ranges traversed. In regions where the mountains are irregular, which is generally the case, the results obtained vary widely and cannot be anticipated.

(6) In general, it is believed that the major difficulty occurs in connection with reflections from mountains. This reflected energy either adds to or subtracts from the energy which is propagated in a direct line, depending upon the difference in path lengths and the phase shift at the reflecting surface. Multiple courses are often found to be crooked, while in numerous other cases they are found to be remarkably straight and will lead a pilot directly to the station.

(7) Multiple courses may appear in the following manner: bounded on both sides by the same characteristic signal; bounded on one side with an A and on the other side with the N as would normally be expected; and the reciprocal of this condition with the A and N on improper sides of the course. In some cases, courses have been found to appear and disappear without continuing into the station from

which they emanated, but as a general rule they can safely be used for homing purposes.

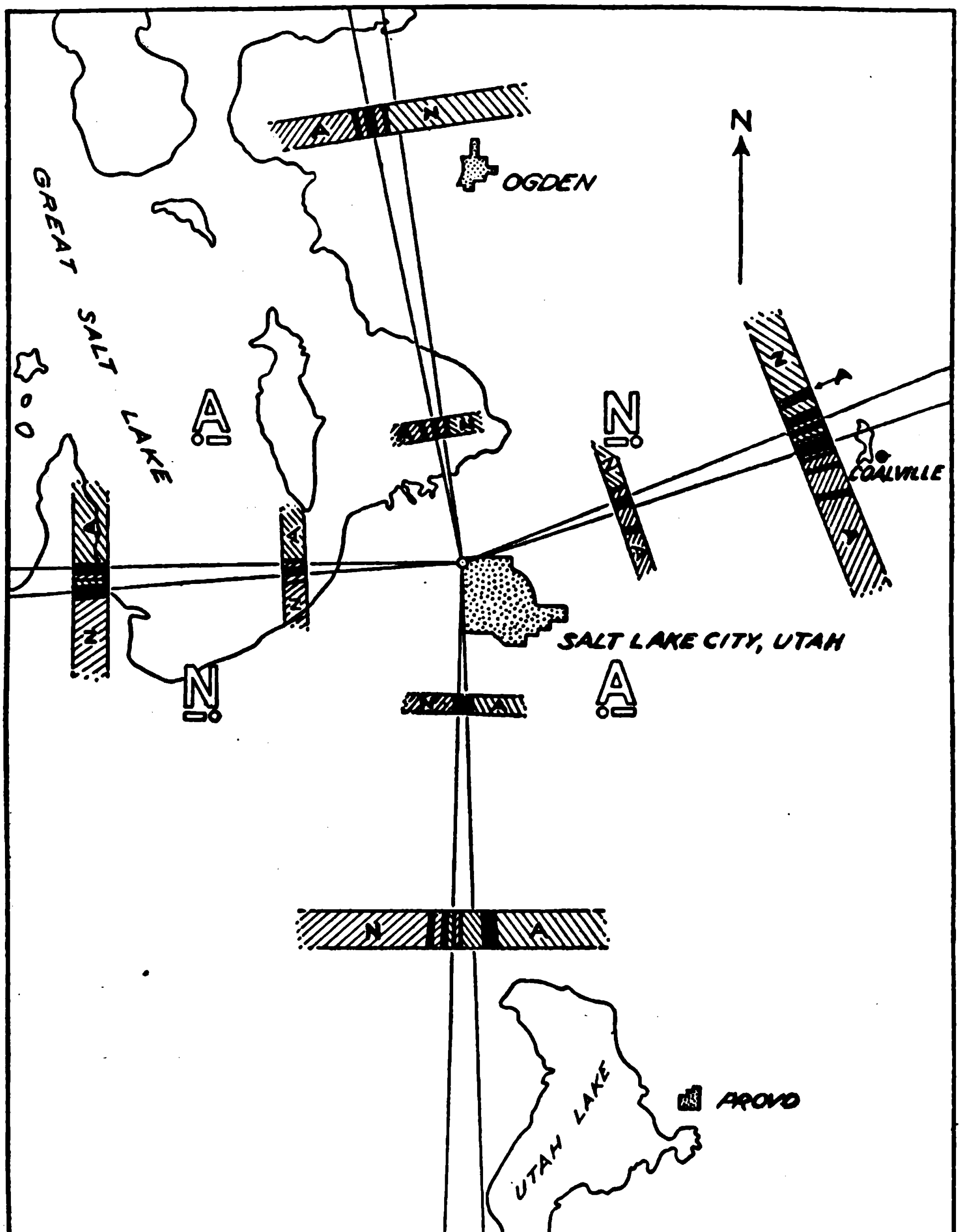


FIGURE 26.—Multiple courses observed on Salt Lake radio range at elevation of 10,000 feet above sea level.

b. Bent beams.—Bent courses, sometimes called "dog leg courses," are usually of little consequence, since the bend is generally small and

away from and around the obstruction that caused it. However, in mountainous country, bends have frequently been found that necessitated a change of compass heading of 45° for a short distance in order to stay on course. Several such bends may occur on a range in a short distance. Obviously such a range would be hazardous to a pilot who was not familiar with that particular range and its peculiarities. These conditions may be found anywhere but are generally confined to hilly or mountainous terrain. A bent course creates the impression that the course is swinging if the airplane proceeds on a straight line.

c. False cones of silence.—(1) Frequent reference is made to so-called false cones of silence, the term being misapplied to what is actually a "fade." Fading may occur anywhere, but it is generally confined to hilly or mountainous terrain and moderately low altitudes above ground. Occasionally, fading has been noted when flying at low altitude over high voltage transmission lines. The degree of change in signal strength is not constant, some fades being barely perceptible. Fades in which the signal level drops by as much as a 1 to 10 ratio are unusual except in rugged mountainous terrain. In the Rocky Mountain regions abrupt changes in signal level of as much as 1 to 100 are sometimes encountered.

(2) Usually, these fades are of short duration and seldom require any change in volume control setting. In this connection automatic volume control in any form should not be used when trying to locate the cone of silence, and noise limiting devices, such as a resistor in the output stage of the receiver, are undesirable. In some cases the distance over which the fade occurs is relatively long. If the latter is encountered when flying away from the station, especially when within, say, 10 miles of the station, the fade is accentuated by the decrease in signal strength due to the increasing distance between the airplane and the station. This often gives rise to such reports as "Distinct fade-out blank miles east." The same fade encountered when flying toward the station may be reported thus, "False cone of silence blank miles east, distinct fade and strong build-up." In the latter case the build-up is more pronounced due to the decreasing distance between the airplane and the station. The closer to the station the fade occurs the more pronounced is the accompanying change in signal strength. In any case the build-up before and after passing through a fade seldom exceeds 2 to 1, so that confusion of a fade with the cone of silence is unlikely.

(3) In conclusion, in determining the location of the station it is not necessary to pass exactly through the cone of silence. A reasonable degree of accuracy may be attained by judicious use of the receiver

volume control. It will be found that in order to continue listening to the range with any degree of comfort, when approaching the station at the lower altitudes, it is necessary to decrease the volume to practically zero. This applies to any range station. As a matter of fact, locating the station by means of the maximum signal zone (using horizontal type antennas) is just as accurate and effective as by any other method.

d. Night effect swinging beams.—Theoretically, the only time that courses actually do swing from their fixed position is usually for a short period at sunrise and sunset. The reason for this is that during this period the electrically ionized region in the stratosphere, known as the "Kennelly Heaviside Layer," is presumed to be changing its position enough so that the sky wave is reflected back to earth to distort the pattern formed by the field strength of the ground wave, causing the overlap areas to shift positions and the beam to swing. This has been almost entirely overcome by substituting for the loop antenna a system of four steel tower radiators located at the four corners of a large square plot and fed from a transmitter in the center through underground transmission lines. The pilot when flying on a beam of the old type beam station should try to fly the center line of the swings. Near the station this night effect disappears.

e. Misalinement of beams.—The position of the center line should be within 1½° of the published bearing but sometimes it is much farther off than this amount. In a moderate thundershower it was noted that the west course of the Salt Lake range moved northward 13.2°. The other legs shifted from 6° to 11°. The reason for this is the change in the total antenna resistance of the transmitting towers, change of the moisture content of the ground, or a change of the height of the water table under the ground due to the sudden shower. However, a monitoring system is maintained. Not one but several receiving stations are charged with the responsibility of listening to each range for evidence of course deviation or other fault. Any departure from normal is investigated immediately and warnings broadcast to all concerned.

67. Simultaneous ranges.—*a.* Many of the difficulties described are avoided by the use of the five-tower vertical radiator type range stations which broadcast voice and range signals simultaneously. The four corner towers broadcast the N and A signals of the range system, while the center tower broadcasts voice signals. The carrier of the center tower is on at all times, this continuous carrier being of material assistance in radio compass operation; the carrier of the corner towers is on only at those instants when they are putting a dot or a dash on

the air; thus while the N signals are being broadcast no carrier is emanating from the A towers and vice versa.

b. With the simultaneous system, the N and A signals are modulated at a 1,020 cycle (audible) tone. Most of the audible portions of the male voice are in the lower end of the frequency band of 200 to 3,000 cycles, with some overtones, harmonics, etc., going considerably higher and some tones lower than this range. There is comparatively little of the human voice right at the 1,020 cycle frequency, so that the elimination of voice frequencies within a narrow range centering at 1,020 cycles has little appreciable effect on speech intelligibility.

c. To use this system effectively, the airplane receiver circuit must contain a small filter unit. One band of this filter cuts out everything but audio frequencies in the vicinity of 1,020 cycles. In other words, it cuts out all voice signals except the few that happen to be at this frequency, leaving the range signals undisturbed. The other band cuts out everything in the vicinity of 1,020 cycles, permitting all other frequencies to pass through. It cuts out the range signals, permitting voice signals to come through to the headset without interference from the range signals. These filters have a three-position switch, permitting either voice signals alone to pass, range signals alone, or both.

d. In operation, the pilot flies with the filter switch set on "both." He hears the range signals, and if a voice broadcast comes on he can usually read either the voice or the range signals without difficulty—just as you can listen to the music or the voice as you desire when someone is speaking on a commercial broadcast with a background of music. If, due to static or some other cause, the voice and range signals interfere, the pilot can, by moving the filter selectors switch to "voice" or to "range," receive whichever signal he elects, alone and without interference from the other.

e. The obvious advantage of this arrangement is that one is able to receive all the weather information broadcast and at the same time to have continuous range signals for directional guidance. Another great advantage is static elimination; by putting the filter switch on range, only those signals having an audio frequency of or close to 1,020 cycles come through to the headset, and therefore much of the static as well as the voice interference is eliminated.

68. Marker installations.—*a. General.*—Because definite fixes are not provided by the radio range station, excepting when passing directly over the cone of silence, marker beacons have been included in the Federal airways system.

b. Marker beacons.—A marker beacon is a low-powered omnidirectional radio station transmitting a characteristic signal, such as V

(. . . —), about every 10 seconds. The marker is located at a point along the on-course signals of a radio range, and the transmission of its signal is made on the same frequency as that of the associated radio range station. If the marker is located at the intersection of two radio ranges the signal is alternately transmitted on the frequencies of both stations. All markers of this type are also equipped for voice transmission to aircraft on 278 kc. Pilots may communicate with these stations to request weather reports, traffic control instructions, etc., receiving reply on 278 kc. The characteristic signals transmitted by these stations can be received for a distance of from 3 to 10 miles. The marker beacons operate when more than one-tenth of the sky is covered by clouds or when the visibility is less than 3 miles. There are relatively few markers of this type in operation on the Federal airways system.

c. Fan markers.—The fan markers are high frequency radio transmitters installed at some distance from the radio range across one or more of its on-course signals. These fan markers operate on a frequency of 75 megacycles, emitting a signal which may be received aurally or visually depending on the receiver installation in the aircraft. Army Air Forces marker beacon receptors currently in use utilize the visual signal only. The signals are keyed to conform with the number of the on-course signal across which they are located. The first on-course signal in a clockwise direction from true north is No. 1, and the fan marker, if any, on this on-course will be keyed with one dash; the markers on the remaining legs are keyed to correspond. The signals emitted by the fan markers, their name, and the distance from the marker to the radio range station is shown in the radio facility charts. Passing over a fan marker definitely establishes the position of the aircraft, and position reports, for airway traffic control purposes, are made by reporting time and altitude over the marker. It must be noted that no voice facilities are operated in connection with the fan marker and position reports must be made to the associated radio range station.

d. Station location markers.—Station location markers are being installed at all radio range stations. These markers also operate on a frequency of 75 megacycles but are not keyed, and emit a steady signal vertically into the cone of silence, thus definitely establishing the position of the aircraft over the station. This signal too may be either visual or aural or both, depending on the receiver installation. It should be noted that the station location marker transmitters operate on a power of 5 watts and that the markers are received only up to limited altitudes over the station. Although the visual marker beacon

receptors are in some instances actuated by interference, reception of the station location marker signal plus the fade and surge of the cone of silence positively locates the radio range station.

69. Weather broadcasting stations.—*a.* Radio range stations, with a very few exceptions, are equipped for voice communication with aircraft. Continuous listening watches are maintained on the itinerant aircraft frequencies, Army aircraft frequency, and on an airline aircraft calling frequency. Weather reports for the route being flown, winds aloft reports, and terminal forecasts may be requested from all radio range stations equipped with voice facilities. A number of radio range stations, those serving terminal points and others at strategic locations along the airways, broadcast weather reports at hourly intervals. Consult the Air Corps Radio Facility Charts, T. O. 08–15–1, for time of broadcast and route coverage of all weather reporting schedules. Weather reports, winds aloft reports, and terminal forecasts are also available at all Army airways communication stations and will be broadcast by these stations upon request.

b. TM 1–460 should be secured by instrument flying trainer instructors. The phraseology used in weather report broadcasts, position reports, and other radiotelephone communication which is prescribed therein should be observed by the student and instructor so far as applicable throughout the instrument flying trainer course.

70. Airport traffic control towers.—Airport traffic control towers are installed at many commercial, municipal, and Army airports throughout the country. The tower operators exercise control over air traffic only within a short distance from the airport for the purpost of directing take-offs, landings, taxiing, and related maneuvers. They have no jurisdiction over traffic on the airways. Because in most instances radio ranges with their associated voice stations are located at airports having airport control towers, it is necessary that pilots direct their calls to either of these two stations. Use the expression "Tower" when calling airport control towers and the expression "Radio" when calling a radio range station. Similarly the expression "Army airways" is used when calling an Army airways communication station.

Section II

RADIO RANGE ORIENTATION

71. General.—*a*. Radio range orientation can be taught more thoroughly and in less time in the instrument flying trainer than in actual flight. Several factors contribute to this. Signals may be exaggerated during the early stages of instruction. The "flight" may be momentarily "suspended" at any time and any confused point in the problem straightened out and the problem then continued (obviously impossible in actual flight). Perfectly clear signals and interphone are available at all times. On the chart an accurate tracing of the entire problem is available for later discussion and analysis, showing beyond room for doubt or argument just where the student under the hood made his mistake.

b. Before the student gets out of the trainer at the end of an orientation exercise, his chart should be turned over. Then go over the entire problem on a blank chart and have him explain his reasons for the various courses flown. Each problem should be executed at least once with the rough air turned on. Occasional problems should be done with various instruments covered up to insure that the student is not learning to depend too much on any one group. Since trainer instruction can go on regardless of weather, all phases of radio navigation should be thoroughly mastered before considering the course completed.

c. All of the following systems and procedures may be taught and practiced until, when finally using them in the air, the pilot knows exactly what he is to do and precisely how to do it. This practice can and should include such peculiarities of radio ranges as bent beams, swinging beams, multiple courses, etc. It should be borne in mind that training received in the trainer will be good only as long as the instruction is good and the signals properly simulated. The

various exercises and methods should be taught in the order in which they are outlined in the section dealing with orientation methods. Inasmuch as beam bracketing must be used in all subsequent exercises, it should be taught first. Before starting radio, however, the instructor should make sure the student is familiar with range signals. With the headset on, the student should run his finger slowly back and forth across various parts of a radio range chart while the instructor sends him the proper radio range signals for the position of his finger relative to the beams. When it is apparent that the student knows what to expect from the range signals, have him look away from the chart, run his fingers across the chart, and explain from the sound of the signals the position of his finger. When it is perfectly clear that the student understands the signals, he is then ready to get into the trainer and start practice on beam bracketing.

72. Trainer radio range operation.—When working orientation problems, great care should be taken to insure smooth fading or building up of signal strength. A sudden change is not natural to radio reception and gives information to the student in the wrong manner, especially in fade-out problems. It is equally important that the A and N control be given close attention in order to maintain proper continuity of signal from a clear N or A through the twilight to the "on-course." The instructor should watch the position of the inking wheel of the recorder, in relation to the radio station on the map, and move the controls as necessary to make the signals sound right. The instructor should know how the signals sound in actual flight and be able to duplicate them by ear. There are occasions when it is advisable to exaggerate signals. When a beginner in radio flying is drifting off an on-course, it is often difficult for him to recognize the fact immediately and he frequently misinterprets A's for N's. Giving him strong, exaggerated signals at this stage will speed up his progress appreciably. As his perceptions improve, the signals should be gradually made to duplicate the actual radio as he will hear it in the air.

73. Instrument flying trainer charts.—*a*. Instrument flying trainer charts have been made available to all service activities. Air Corps T. O. 08-5-28 contains a list of charts available together with a description of the charts.

b. Figure 27 is a typical example of the instrument flying trainer charts. Note that space is provided for the student's name, the date, time (duration of the problem), and the instructor's initials. The data for three different flights may be entered and the chart should be used several times, provided the courses previously recorded are not such as to confuse the instructor. The same chart is printed on the

reverse side to conserve paper, making its use in six problems possible. The used charts should be filed for reference until the students whose records appear thereon have completed their courses. Charts which have been used for an approach problem should be used for orientation

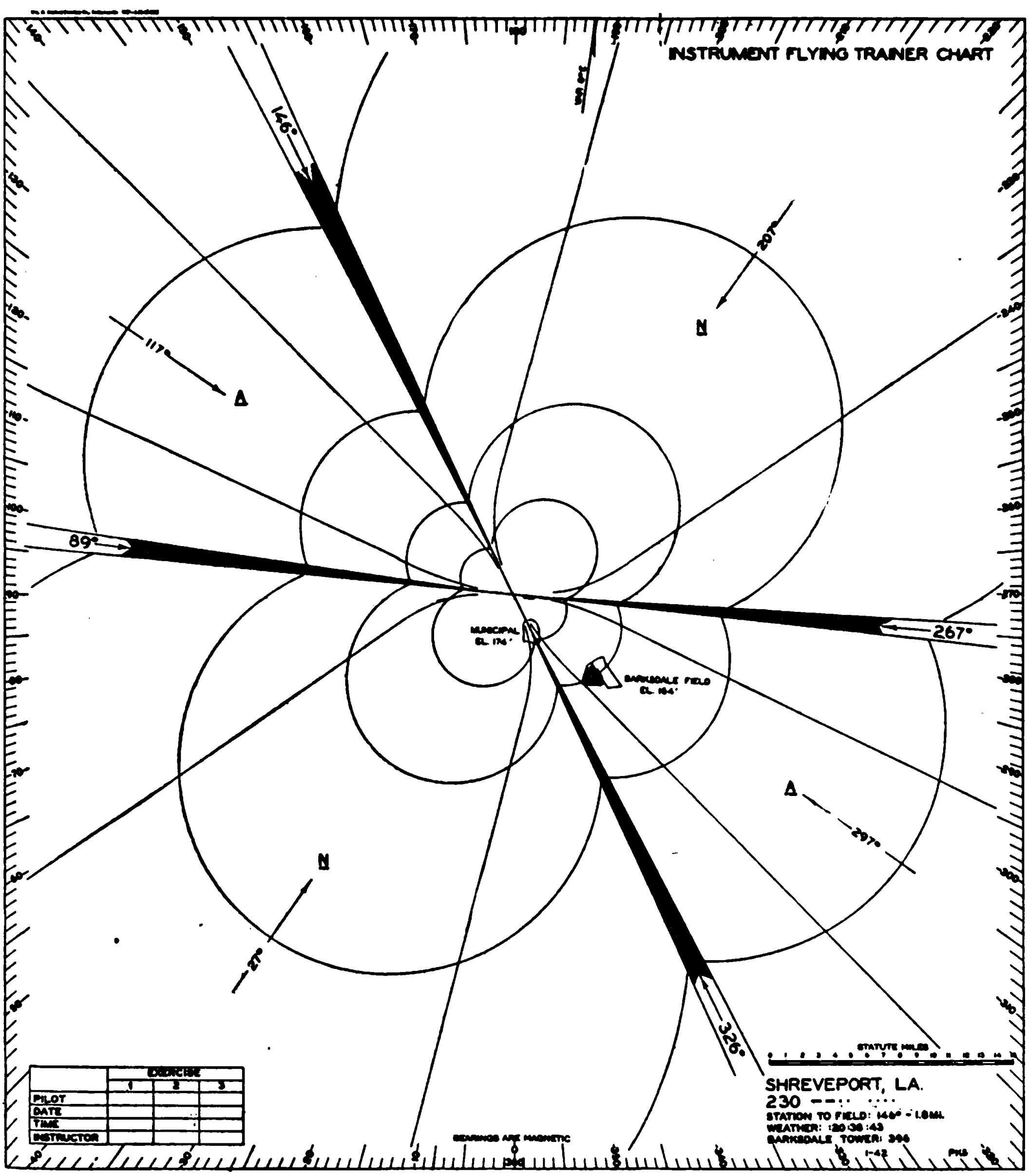


FIGURE 27.

problems thereafter because under ideal conditions the tracks on approach problems should be very nearly identical.

c. Charts covering square stations, scissor or squeezed pattern stations, crow-foot stations and others showing two or more radio ranges are available. Signal strength in different types varies, therefore the

lines of the equal strength are drawn on the charts. The innermost of the signal strength lines represent 50 on the volume control, decreasing until the outermost line represents 20. The lines for 60, 70, 80, 90 are not shown and should be imagined, and the volume control used accordingly. The 15 line of the A–N beam shift control dial is indicated to either side of each on-course signal. As the recorder approaches the on-courses, represented by a shaded beam, the A and N control should be gradually turned until a pure on-course is given as the recorder intersects the beam. The rapidity with which this control is shifted will of course depend on the distance from the station and the angle at which the beam is being intersected. For example, referring to the chart (fig. 28), the student is flying southwest from the theoretical position "A." The volume should be set at 37 and the A and N beam shift control as far off-course in the N quadrant as possible, which is 15. The student flies southwest for a few minutes, bringing him to position "B." The volume should be changed to 32 during this change of position. The student continues to fly southwest, reaching position "C." During this time the volume will be changed slowly to about 21, and the beam shift control will be very gradually changed from 15 (at B) to 0 (at C). Turning northeast the beam shift is kept at 0 until the center of the beam has been crossed. It is then gradually turned toward the A side until 5 is used as the recorder reaches point "D." The volume will have gradually been increased to 25. Turning farther toward northeast the volume is increased to 30 by the time point "F" is reached, while the A and N control will have been moved from 5 on the A side through 0 to about 4 on the N side. The proper fan marker will have been given as the recorder passes position "E." As the flight progresses it will be noted that both volume and beam shift controls will have to be moved more rapidly.

d. Because the proper operaton of the A and N control as well as the volume control is of the greatest importance, it is recommended that instrument flying trainer officers, who must be experienced pilots, monitor the instrument flying trainer instructors at least once weekly, while a student is being instructed. The extra phone jacks located near the rear of the desk on each side should be used for this purpose. Poor or inaccurate manipulation of the controls should be pointed out to the instructors in order that such mistakes may be corrected before they develop into a habit.

e. Because all radio range stations in the United States are now equipped with 75-megacycle station location markers it is not neces-

sary to show a symbol for these installations on the charts. These markers should be given when the problem being flown requires it.

f. In addition to the single radio range charts, cross country charts and instrument landing charts are also available to the service.

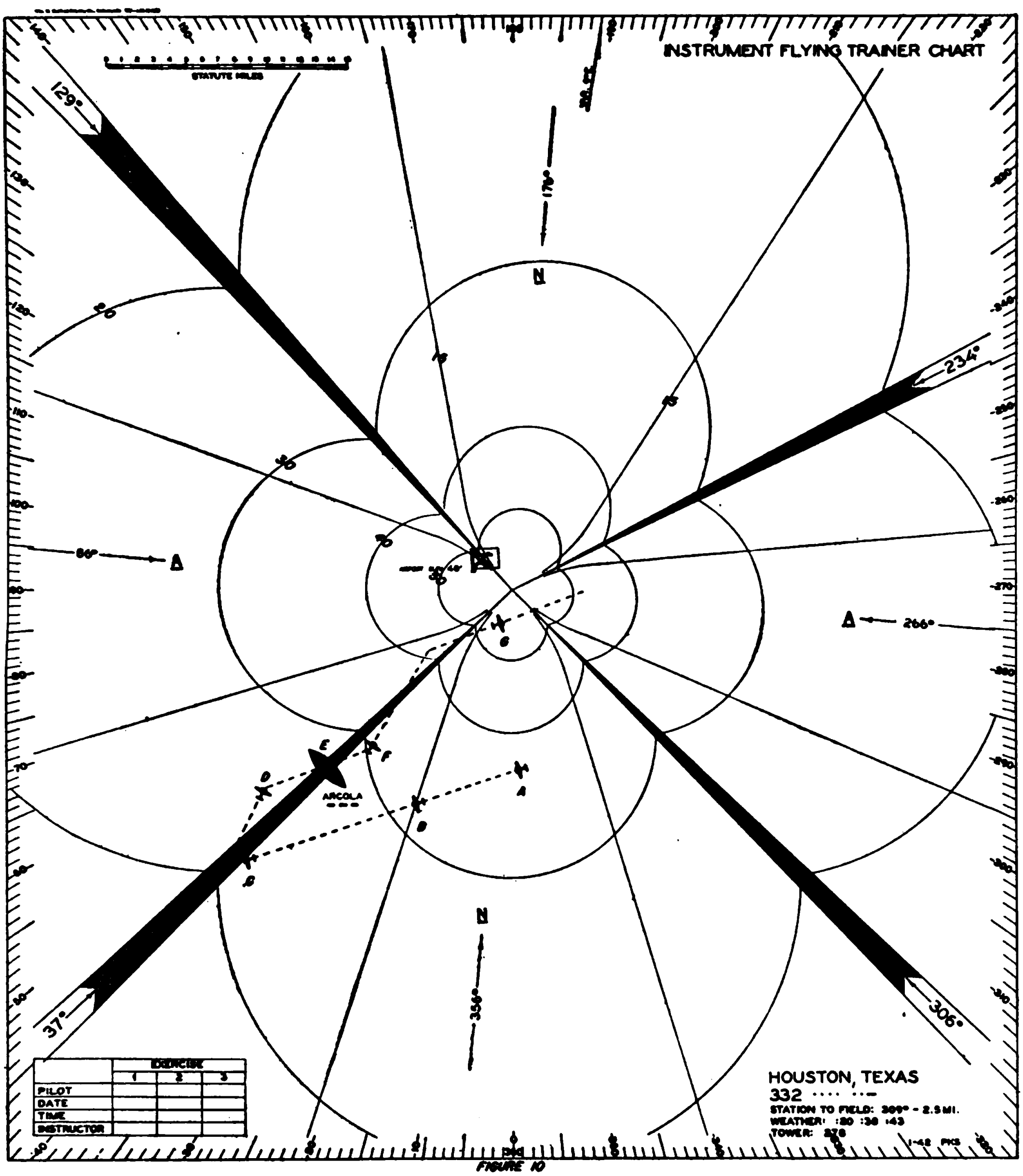


FIGURE 28.

74. Placing recorder.—Placing the recorder on the chart properly is of the utmost importance, since the trainer can draw lines on the chart in the proper direction only if the recorder heading agrees with the trainer heading. The instrument flying trainer charts furnished for the use of the service are charts of actual radio range in-

stallations at selected localities in the United States. These charts are scaled for use with the variable speed recorders of the type C–3 and C–5 instrument flying trainers, having a recorder travel of 0.84375 inch per minute at an indicated air speed of 160 miles per hour. Radio ranges, landing fields, obstructions, etc., are shown in their true relation to one another on these charts. The bearings given are corrected for magnetic variation as they are on sectional aeronautical charts and radio facility charts. Because magnetic variation will differ at the locality where the instrument flying trainer is being used from that of the area for which the chart has been produced, an allowance must be made for this difference. To make this correction lay off the magnetic variation shown on the chart on the compass rose thereon and draw a line from this bearing to its reciprocal on the lower edge of the chart. Set the recorder in such a manner that its front edge is at right angles to this line, or place the chart on the table in such a manner that this line intersects the front edge of the table at right angles. In the latter case set the recorder so that the top edge of the recorder is parallel to the top edge of the table. The inking wheel is then turned by means of the large recorder gears until it is traveling in the same direction on the chart as the trainer is headed. This may be verified by noting the pointer on the radio compass control, provided the radio compass control is properly set.

75. Application of wind drift to recorder.—*a.* It is essential that drift be applied in many orientation problems. The habit of teaching all orientation problems in "still" air encourages the student to depend altogether too much on compass headings to identify a beam. This tendency is present in nearly all students and can often be cured only by the application of sufficient drift so that the information obtained from the compass alone will lead the student to believe he is on a different beam than where he actually is. This is particularly true of true fade-out problems. If the student is permitted to identify the beam from the compass heading (which often cannot be done in actual flight) he will not have learned the system, and the first time he finds himself faced with the necessity to use it, if a considerable drift angle exists, he may become hopelessly lost.

b. At stations where the C–2 or C–4 instrument flying trainers are available as well as the C–3 and C–5 trainers it is advisable to use the C–3 or C–5 trainers for problems which include wind drift. If the C–2 or C–4 trainers must be used for such problems the drift is simulated by rotating the recorder gears downwind. In this case the most practical amount of drift simulated is 30°, one "electrical notch" on the large recorder gears.

c. To apply wind in problems flown on the type C-3 or C-5 instrument flying trainer, it is only necessary to set the desired wind direction by rotating the "wind direction" crank to the proper dial reading. For example, if the problem calls for a wind from the west, the dial will be turned until the figure "27" is opposite the pointer. The desired wind velocity can then be applied by turning the crank marked "wind velocity" to the proper setting.

d. Since the recorder speed and direction of travel on the type C-3 and C-5 trainers vary with both the indicated air speed and the applied wind, the path of the recorder inking wheel represents the actual ground speed and track of an airplane flying under identical conditions in the air (assuming the indicated air speed to be the same as the true air speed). This makes it possible to simulate radio range flying with a higher degree of realism than has heretofore been possible.

e. When using the wind drift mechanism the qualified instructor should be able to introduce any desired drift angle by the proper selection of wind velocity and wind direction. Drift angles should be suited to the particular problem being flown and should demonstrate the effect of the wind. In the examples used to demonstrate the weakness of certain orientation procedures under some conditions, it is necessary to use a wind of maximum available velocity (60 mph) at right angles to the course being flown in order to introduce the desired drift angles. The maximum velocity should only be used in this type of demonstration. It must be considered that the effect of the wind diminishes as the speed of the aircraft increases. Hence the drift angle produced by a 60 mph wind on the instrument flying trainer traveling at 120 mph is equivalent to the angle produced by a 120 mph wind on an aircraft traveling 240 mph. After the student understands the limitations of the various systems, the effect of wind should be introduced in every problem, in velocities and direction which will be of maximum training value. For instance, moderate head winds becoming tail winds after a procedure turn has been made have a considerable effect on maneuvers involving timing, such as approach procedures. This is true particularly if the procedures are worked at reduced speed. It is desirable to make an upper air broadcast reporting winds of different velocities at different altitudes, in which case the proper wind must be introduced depending on the student's flight level. A detailed explanation of the wind diagram which will be useful to the instructor will be found in section VI, TM 1-205.

76. Limitation of orientation methods.—*a.* The limitations of range orientation in general and of each method or system in par-

ticular are the most valuable facts for the pilot to know. It is vitally necessary to understand the limitations of each system and the specific circumstances under which it will work in order that the pilot may know which method to use under given conditions. The various methods tested, proved, and used by acknowledged expert instrument pilots are outlined in the following paragraphs, along with conditions under which they will and will not work. Any short-cut method which deviates from those which follow should be looked on with suspicion and thoroughly analyzed by an expert before an attempt is made to use it.

b. The complaint often arises that it is unnecessary and possibly confusing to learn so many systems. A little study of the various conditions under which any one system will fail, often with disastrous results, should convince any common-sense pilot of the necessity for a thorough understanding of a subject on which one day his life may depend. Mastery of the several systems will, at first, appear complicated and difficult of accomplishment while under the hood or on instruments. A few hours' practice in the instrument flying trainer, with the charts available for analysis of when, how, and where the errors were made, will show that this is not so. And when the pilot has mastered the various systems to the point where he can promptly choose the proper one for any given set of conditions, he will one day suddenly realize that he is no longer using any system but merely going through the maneuvers that are common sense for that particular set of circumstances.

c. A study of the following text will show that the selection of a particular method is usually based on the pattern of the station being worked. It will also be noted that the bugaboo of range orientation is high wind with its accompanying large amount of drift. It is a fact which can easily be checked that high winds of velocities of 60, 80, or over 100 mph do occur. Even with modern, fast airplanes such winds produce angles of drift which will cause some systems of orientation to fail on some station patterns; and with the slow aircraft—150 mph or less—the drift angles become surprisingly large.

d. Static discharges at times become sufficiently severe to cause total blanketing of radio signals for a portion of an instrument flight. Under such conditions the flight may be continued by dead reckoning navigation (provided weather conditions permit). If properly done dead reckoning should bring the pilot to his planned destination. If it fails to do so and the pilot does not know where he is the reason must be an unknown high wind or an unpredicted wind shift. It will then be necessary to work an orientation problem on the radio range

which can be received after the severe static has been left behind. It follows that range orientation will be used very frequently under conditions of high and unknown wind. It further follows that to be depended on, an orientation system must be one that will work in spite of large drift. When it becomes necessary to work an orientation problem under these conditions safety demands that it be flown at an altitude well above the highest obstacles within the area where the flight could possibly be.

77. Beam bracketing.—*a. General.*—(1) Radio range orientation is the art of finding and identifying a radio beam for the purpose of establishing the position of an aircraft in relation to the radio range station. After this line of position is established the next step is to track down the beam and follow its right-hand edge to and over the station. This latter step is common to and is the goal of all orientation systems. It is also, actually, the most difficult phase of orientation problems.

(2) Properly bracketing a beam enables the pilot to obtain, in the shortest possible time, the heading which will keep him on the right-hand edge and thus enable him to fly a straight course to the station. It enables him quickly to determine his drift by comparing the heading with the published beam bearing, the difference being the drift correction.

(3) Since there is almost never a no-wind condition in bad weather, it becomes obvious that the heading required to stay on the beam edge will often not agree with the published beam bearing. They will not even be close in most instances. Since the drift with the slower types of aircraft may be anything up to 40° or more on either side, the heading which will maintain the beam edge may be anywhere within an angle of nearly 90°. Since beams are approximately 90° apart in most cases, it becomes obvious that the published bearing of the beam has supplied the pilot with practically no information regarding the compass heading he will have to maintain to follow it.

(4) It becomes equally obvious that the pilot who would consider himself skilled at radio range flying (whether orientating from a lost position or merely following beams cross country) must master a method of bracketing and following a beam which is independent of, and not materially affected by, wind conditions and drift.

b. Method.—The following method answers this need:

(1) *Basis of method.*—Upon encountering the beam, continue straight through it, noting the heading *a*(1) above. When the first opposite off-course signal is received, start a standard rate turn to the left. Continue this turn until back to the edge of the beam (pro-

vided, however, that this turn must not exceed 180°). Upon reencountering the beam edge, note the heading (2) and immediately start a standard rate turn to the right. (See fig. 29.) Continue this turn until the first off-course signal on the right of the beam is again picked up. Upon hearing this first off-course signal, again start a turn to the left. The heading which first took the aircraft into the beam (1) and the heading noted upon again encountering the beam (2) are the original brackets, except in the case where the first turn is 180°, as in figure 30. In this case headings (2) and (3) are used. Somewhere between the two is the heading which will maintain the beam edge. Continue the left turn to a heading which reduces the bracket by about 25 percent, then hold this heading until the beam is reencountered. Upon reaching the beam edge, promptly start a turn

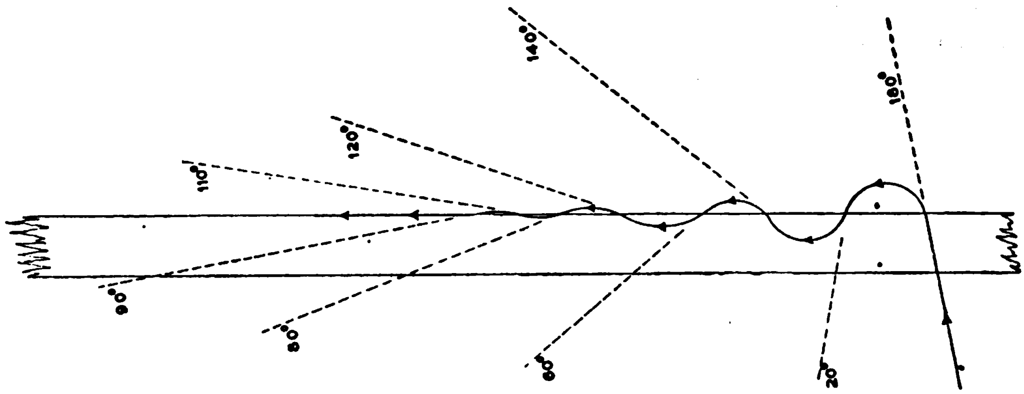


FIGURE 29.

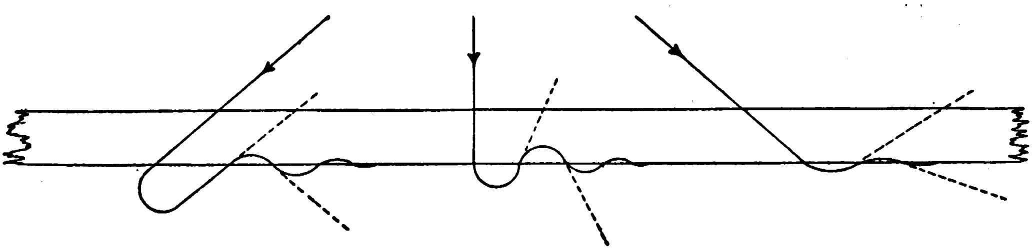


FIGURE 30.

to the right to a new heading which will reduce the right-hand side of the bracket by about 25 percent. Continue this process, reducing the bracket by about 25 percent with each turn. It will be noted that each pair of turns cuts the size of the bracket in half. The process should be continued until the brackets are reduced to from 3° to 5°.

(2) *How it is done.*—(*a*) Upon encountering a beam, note and hold the heading. While riding through the beam compute the reciprocal heading, since the ensuing left turn must not exceed 180°. With this value in mind, consider it as a barrier beyond which the turn will not be continued, but not as the object of the turn. The object of the

forthcoming left turn is to get back to the beam. (A glance at fig. 30 will make clear why the turn should not be more than 180°.)

(*b*) With the barrier heading fixed in mind, the pilot has nothing to do but hold his heading and wait for the first opposite off-course signal. To take a specific example, assume the heading is 180°, and that in entering the beam an N was left behind. Upon the first A received, start a standard rate turn to the left. Listen sharply to the radio signals and as the beam is again just barely reached, note the heading and at the same time start a standard rate turn to the right. Say the heading at this instant is 20°. (The barrier in this case was 0° and was not reached.) It will be noted that a turn of 160° was made and the headings of 180° and 20° are the original brackets (see fig. 29). In the turn now being made it is desired to reduce the size of the bracket by 25 percent. One-fourth (25 percent) of 160° is 40°, so instead of turning to a heading of 180° the turn is continued only to

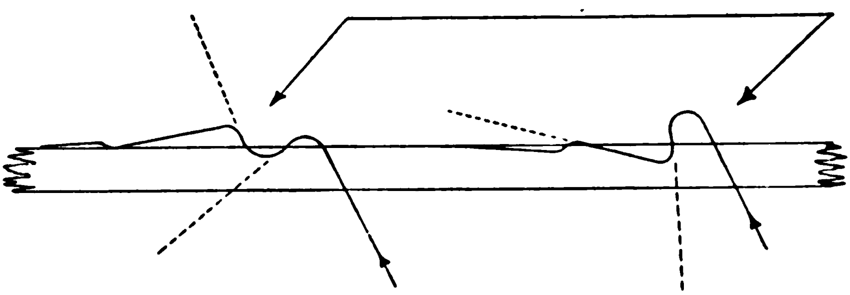


FIGURE 31.

140° (40° less than 180°). Upon reaching this new heading hold it until the first A is received. Upon hearing the A, start a turn to the left. Since it is desired to reduce the left side of the bracket the same amount as was just done to the right side, this turn will be continued only to a new heading of 60°. Upon reaching this heading hold it until back to the beam edge. It should be noted that the bracket is now reduced from a spread of 160° to a spread of only 80° or just half its original amount. Upon reaching the beam edge, immediately start another turn to the right. The spread of the bracket now being 80°, one-fourth of it will be 20°. So 20° is taken off the heading of 140°, which was the previous right-hand side of the bracket, and the turn continued only to a heading of 120°. This heading is held until the first off-course A is again received. Upon hearing the A, start turning left to a new heading of 80°. (This is stopping the turn 20° before reaching the previous inbound heading of 60°.) Note that the bracket is now reduced to a spread of 40°.

(*c*) Continuing in the same manner to reduce the bracket further, the heading is held until again back at the beam edge when another

turn to the right is immediately started. Again taking off one-fourth (one-fourth of the 40° spread being 10°), this turn to the right will be continued to a new heading of 110°. (The previous outbound heading was 120°.) Upon again receiving the A, turn left as before, this time to a heading of 90° (10° before reaching the previous heading of 80°). Repeat the process again, reducing the bracket by 5° on each side (the spread now being only 20°), and the bracket is down to only 10°; once more and it is reduced to 5°, and the final landing is found to be 100°.

(*d*) From the above description one might make the mistake of assuming that the beam heading is always the mean of the first bracket. This would be true only if the pilot could make mathematically perfect turns, if his ear was a delicate electrical instrument subject to no error, if the beam were not interrupted approximately one-fifth of the time for identification signals, and if no drift existed.

(*e*) If the pilot is slow in recognizing the off-course signal, or if an identification signal occurs at the instant of running off or into the beam, a sawtooth bracket will result (see fig. 31). For example, while turning to the right to find the edge of the beam, for either reason given above, the turns which determine the original bracket are often carried too far in that direction. Or if the error occurred while going into the beam the turn to the left would be too great and the bracket "lopsided" in that direction. This condition can be readily recognized when it occurs. The effect, as shown in figure 31, is that if the original turn to the right has been too great, it will take a long time to get back to the beam. The next turn to the right to get out of the beam will result in reaching the off-course almost immediately. The situation is easily remedied. If it takes a long time to get back to the beam and only a short time to get out of it, remove very little or none from the inbound bracket. If a long time is taken to get out of the beam and only a short time to get back in, reduce the bracket on the right (outbound) turns little or none. The brackets should be reduced equally on both sides only when the straight flight between turns is approximately equal on inbound and outbound headings. While this sounds complicated, it is not difficult to do. It is much easier to demonstrate than describe.

(*f*) The method of bracketing a beam just described is termed "mechanical bracketing." The pilot who has mastered the method can reduce the amount of turning and the time required to obtain a narrow bracket on the beam heading by anticipation and making use of the changing signals. This is particularly true when working within a few miles of the station where the signals are sharp and

the changes rapid and distinct. For example, when making a left turn to get back to the beam as in mechanical bracketing, and an obvious increase in the strength of the background indicates that the beam is getting closer, it is not necessary to turn farther to the left. As soon as the background is definitely increasing, the turn to the left should be stopped and the heading noted and held until close to the beam. Then, instead of waiting until the actual beam edge is intercepted, the turn to the right should be started just before the beam edge is encountered. In this manner, the original bracket can easily be cut in half; a pilot who is really skillful at bracketing can very often judge the change in signals well enough so that even if approach-

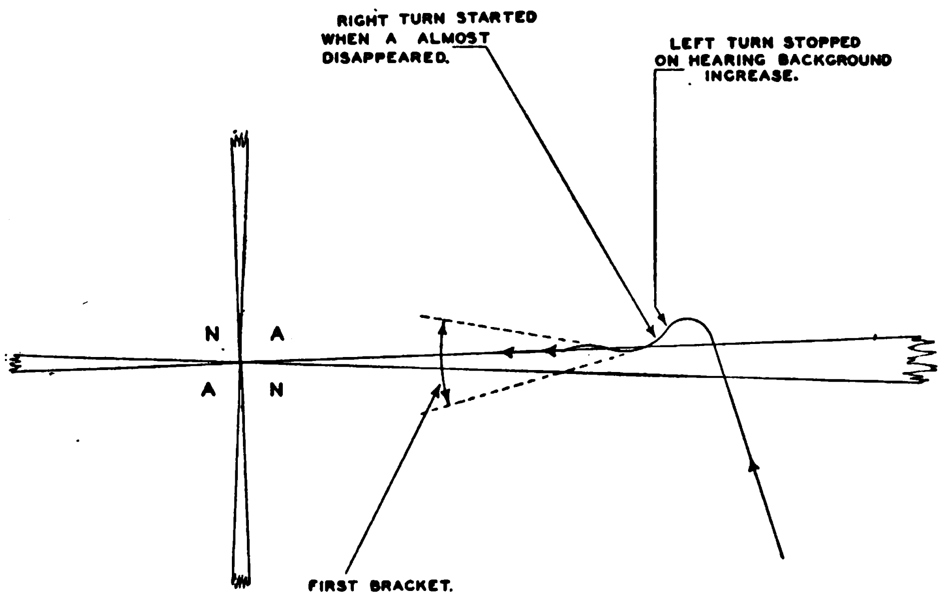


FIGURE 32.

ing the beam at extreme angles his first bracket will be only 15° or 20° (fig. 32). Before attempting to anticipate, the mechanical method should be thoroughly mastered. Even then anticipation of the beam should be done gingerly and cautiously with emphasis on not overdoing it and becoming "beam shy" as a result of starting turns too early when approaching the beam. It is better to anticipate too little and depend more on the mechanical method than to overdo it and lose the beam.

(3) *Advantages of method.*—The method is independent of wind and drift and can be used even if no map or knowledge of the particular station is at hand. It makes possible getting squared away quickly and steadied down on the beam edge, with the drift established, while far enough from the station so that only minor corrections to headings are necessary when close in. This results in being able to follow the

definite on-course to the station and consistently to hit definite cones, which in turn does away with having to guess at the approximate position when in the vicinity of the station. It permits of arriving in the shortest possible time at the heading which will follow the right-hand beam edge and a straight course to the station.

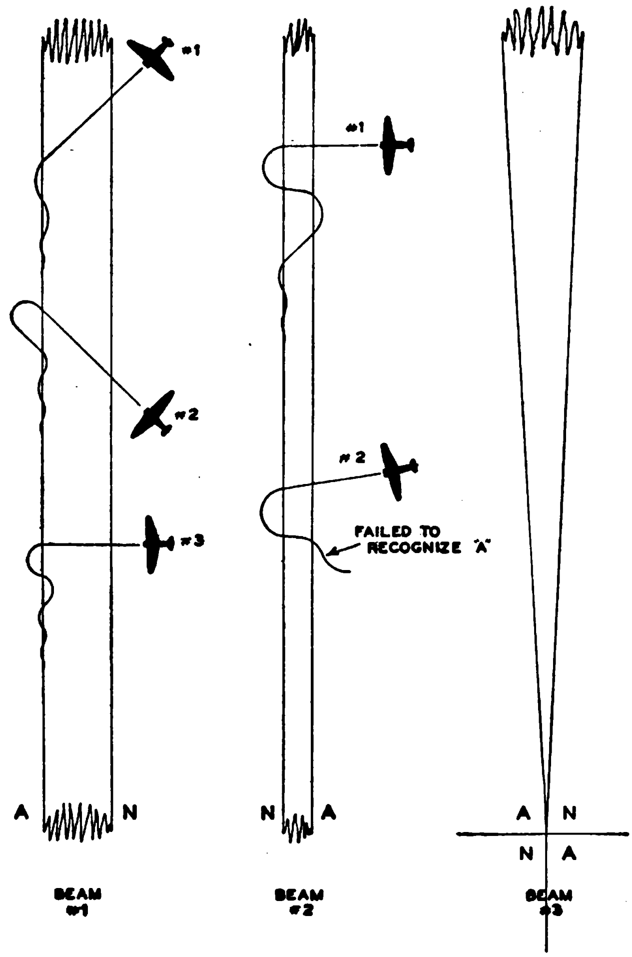


FIGURE 33.

(4) *Disadvantages of method—too much turning and twisting.*—Actually, no more turns need be made by this method; they simply are made earlier and without waste of time.

c. Trainer instruction.—(1) Using the "beam bracketing chart," the purely mechanical method of beam bracketing should be taught first and thoroughly mastered by the student before he is permitted to "anticipate." The wider beams on the chart should be used at first. Without regard to the trainer heading, the recorder should be turned so that the inking wheel will cross the beam at an angle of about 45°. (See fig. 33, position No. 1, beam No. 1.) The first two or three attempts at bracketing should be made with this easy angle of attack.

When the student demonstrates that he has a clear conception of the process of mechanical beam bracketing, the recorder should be set so that the more difficult angles of attack are employed, such as position No. 3 on beam No. 1. As soon as the student is able to cope with these difficult angles of attack, he should be put on a narrower beam such as beam No. 2. The recorder should then be set so that it will cross the beam at approximately 90°. The first right-hand turn to get out of the beam following the first left-hand turn should carry the student back across the beam into the original off-course signal. He will then often fail to recognize that it is the wrong signal and that he is on the wrong side of the beam and will start turning left. This is a tendency which will be found in nearly all students and should be corrected in the early stages of beam bracketing practice.

(2) As soon as the student can successfully bracket a narrow beam and is able to recognize, but not become confused by, the signal on the left, his practice should be done on beam No. 3. Practice on this beam should include not only beam bracketing but also following the right-hand edge of the beam to and over the station A.

(3) Since getting onto a beam and following it to the station is the goal of most orientation work, it is important that the foregoing exercises be mastered before attempting to progress to the more interesting orientation problems.

(4) During all this beam bracketing practice the off-course signal should be clear, loud, and distinct. Do not be afraid to exaggerate greatly the rate of signal change in the off-course zone. After the student knows what he is trying to do there is plenty of time to cultivate his ability to detect faint or slight signal changes. It is also necessary during these early stages of radio practice to "lead" the inking wheel.

(5) At this point it should be stressed that one of the most important things for the instructor to remember is to keep the A–N mixture control (beam shift control) moving smoothly as long as the inking wheel is at an angle to the beam edge. The only time that the background remains at one level is when the inking wheel is parallel to the beam edge. The rate of change of background is of course dependent on the angle of attack. Care must be taken with the rate at which the mixture control is being moved so the solid on-course signal is not given before the inking wheel arrives at the beam edge. It is even more important not to be late with the signal, that is, not to let the inking wheel get into the beam before the solid on-course is given.

(6) Whenever the inking wheel is moving toward or away from the beam, the mixture control must be moved toward or away from

the zero. Avoid holding the mixture control stationary at any time unless the inking wheel is exactly parallel to the beam, as this gives the student wrong information.

(7) Throughout beam bracketing and other radio practice there will be a tendency on the part of the student toward aimless and confused wandering. There will also be a tendency on the part of the inexperienced instructor to let him do it. As soon as the student deviates from the prescribed routine the recorder should be stopped and the student told to hold his present heading. The instructor should then find out what the student's trouble is, why he deviated from the prescribed method, and get him properly started over again with as little loss of time as possible. The inexperienced instructor will often hesitate to cut in on the student, usually through not feeling entirely sure of himself, but he should remember that any time spent in aimless wandering is a dead loss to both the student and the instructor.

(8) When using beam No. 3 (fig. 33) the instructor should bear in mind the characteristics of range station signals close to the station. It should be remembered that not only the beams but the entire bisignal zone narrows down, consequently when only slightly off the beam close to the station the signal should be clear and loud, that is the volume should be increased and the beamshift handle turned far enough so that the A or N becomes clear and loud much closer to the beam than would be the case several miles from the station.

(9) The beginner on radio range flying will invariably be scared into making large corrections when he hears the loud signal close to the station. He must be taught to stick to his brackets, making only small corrections, and at this time he should also be taught to make flat turns, that is to keep the wings level, since banking will distort the signals.

78. Following right-hand edge of beam.—*a.* After bracketing the beam as previously described and the brackets are reduced to 2° or 3°, the next phase of the problem is to maintain the beam edge until close to the station. This will require considerable practice but is essential, as the percentage of cones intersected by the student will depend on his ability to follow the beam edge properly.

b. Due to various factors described elsewhere the edge of the beam is not a perfectly clear-cut straight line. Consequently even if the drift remained constant (which it does not), small changes in heading will be necessary from time to time when following the edge, even though the bracketing has been done properly and the brackets are small. The student should learn to recognize and ride the "fringe." This fringe is that narrow path alongside the beam where the off-course

signal is so faint that the pilot can distinguish it only about one-fourth to one-half of the time. The occasional leaking in of a faint off-course A or N is also contributed to by slight swinging of the beam, and to a ragged edge produced by small local fades and builds.

c. Most students will display a tendency to remain in the off-course signal too long. If the left-hand side of the small bracket already established does not gradually lead back into the beam after a reason-

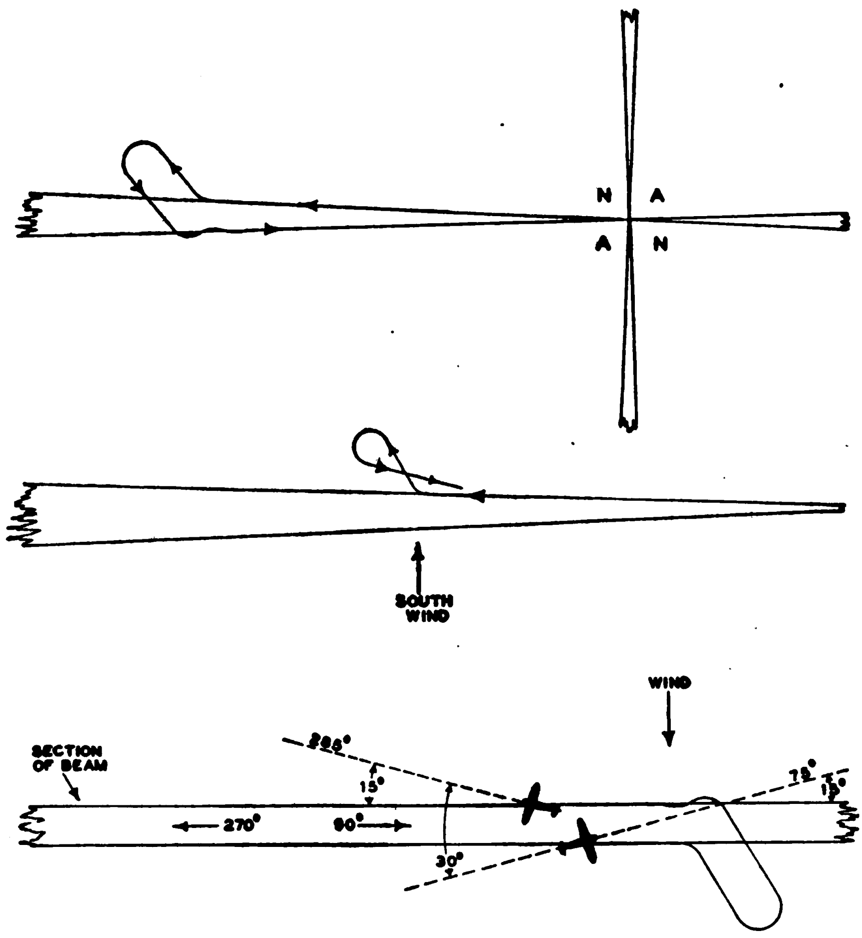


FIGURE 34.

able length of time, the mistake should not be made of making a series of further small corrections. Rather, apply a 10° or a 15° correction toward the beam, and then when the signal sounds as if it would be impossible to hear more than one of two more off-course letters, remove this large correction and return to the small brackets previously established. Then move both sides of the small bracket 3° to 5°. If the right-hand side of the small brackets does not result in reaching the beam edge within a reasonable length of time (depending on how long the previous outbound heading required to reach the edge), a 15° correction to the right should be applied and then removed when the edge

is reached. If good contact with the beam edge is not maintained until close to the station, the last minute or two from the cone is almost certain to produce wild corrections and missed cones.

d. As the station area is approached, the beam narrows. When close enough to the station so that small corrections in heading will take the ship from a slight off-course signal on one side of the beam to an off-course on the other side, the pilot should be content to remain in the middle of the beam and not attempt to find the edge from that point to the cone. The final mile or two is where the insufficiently trained pilot will throw away his chances of getting a good cone. When this close to the station, as indicated by the narrowness of the beam and the sharpness of the signals, all corrections in heading must be made with the airplane held level. If the ship is permitted to bank, the pilot will hear whatever signal the lead-in is pointed toward. If he reacts to an off-course signal caused by banking, and corrects for it, he will really be off-course when he again levels the ship. When he banks and corrects for this latter off-course, pointing the lead-in out into that quadrant, he will hear a loud, clear signal that often will scare him into wild swings that inevitably result in missing the station. The remedy is simply that when close to the station the beam must be bracketed down well enough so that only small corrections are necessary and the turns must be flat to avoid distorting signals.

e. Making flat, skidding turns is not easy, especially "on instruments." A new coordination is required which is entirely different from habits formed in contact flying. It is necessary to make the turns with the rudder and to apply sufficient opposite aileron to keep the wings level. When the new heading is reached it is necessary to continue to hold a certain amount of rudder and opposite aileron until the ship stops skidding. It is definitely recommended that the pilot practice these flat turns without the hood, noting the instrument indications, until he can do it smoothly. To prove to himself the necessity for flat turns close to the station, it is also suggested that the pilot, still without the hood, fly to a position on-course and within 2 or 3 miles of the station, and then roll the ship into a bank first one way and then the other and note the effect on the signals. He will find that while still in the middle of the beam he can bring in either an A or an N merely by banking one way or the other, and that when he levels off again he is still on-course.

79. Procedure turn.—*a. General.*—Turn 45° to the right from the heading that maintained the beam edge. Hold this heading for not less than 45 seconds, preferably 1 minute. Then do a standard rate turn to the left of 180° plus or minus the proper allowance for

existing drift. Hold this new heading until the right-hand edge of the beam is reached, then turn left and bracket the beam in the usual approved manner.

b. How it is done.—While maintaining the beam edge, note the difference between the published beam bearing and the magnetic heading. This is the drift correction. For example, assume the outbound published beam bearing is 90° and the heading necessary to maintain the edge is 75°. A standard rate turn to the right of 45° results in a new heading of 120°. Hold this heading for 1 minute. During this time figure what the new heading will be after the 180° (plus or minus) turn is made. In this problem there was a drift correction of 15° to the left. Therefore, the left correction must be removed and the right correction added (in this particular problem), making a total factor to the right of 30°. A left turn of 180° from the present heading of 120° would be to a heading of 300°. When the drift factor of a total of 30° to the right is applied, the heading to turn to becomes 330°. At the end of the 1-minute run, then, turn to the left to a new heading of 330°. Hold this heading until back to the right-hand edge of the beam, then turn left and bracket in the usual manner. (See fig. 34.)

c. Advantages of method.—It permits habits to be formed which can be carried out automatically and so require little effort or concentration. It permits the maneuver to be accomplished in the steps "one thing at a time" and so reduces the possibility of confusion. It reduces the possibility of drift interfering with the smooth success of the maneuver.

d. Disadvantages of method.—Takes slightly longer to execute than some other methods, but is well worth it.

e. Trainer instruction.—Using the Louisville instrument flying trainer chart, place the recorder on course on the beam near the left edge of the chart. Have the student fly the trainer at a heading of 90°. Start the recorder and apply a wind of 45 mph from the north, 0 on the wind direction dial. The student will fly toward the station, bracketing the beam and establishing his drift angle. Instruct him to make a procedure turn to the south 4 minutes after passing the station. The problem is completed when the student returns to the range station, having established his new drift angle. The track of the recorder should be very nearly identical with that made under no wind conditions if the drift corrections were properly applied by the student. If it is desirable further to demonstrate the effect of the wind, the student may continue 4 minutes past the station, headed

west, and make a procedure turn to the north, intercepting the on-course and returning to the station as before.

80. Average bisectors.—Practically all orientation systems are based upon the use of the average bisectors or the perpendiculars thereto for the original heading of the aircraft. A method for the determination of their values is given herewith for use when these figures are not otherwise available. Add the sum of the inbound magnetic bearings of any radio range station and divide by four. The result will be the magnetic bearing of one of the average bisectors. Add or subtract 180° to find the reciprocal of this bearing for the opposite average bisector. Add or subtract, whichever is most convenient, 90° to or from either of the two bearings thus found to determine the two remaining bisectors. Because the average bisectors are 90° apart, the average bisector of the N quadrants will be perpendicular to the average bisectors of the A quadrants and vice versa.

81. 90° system.—*a. Basis.*—(1) As soon as the A or N is identified, a heading is taken up perpendicular to the average bisector. Two of the legs are then eliminated from the problem, as they are behind and so cannot be intercepted. This heading is held until a beam is intercepted and crossed. On the first off-course signal after riding through the beam, a standard rate turn of 90° is made to the right. This new heading should take the airplane either back into and through the on-course or deeper into the opposite quadrant. If the on-course is reencountered, the ship passed to the right of the station and the leg on the right is identified. In this case the heading is held for 1 minute after encountering the beam edge. At the end of this minute a standard rate turn of 180° is made to the left. This new heading is held until the far edge of the beam is encountered. The right-hand edge of the beam is then bracketed down and followed to the station.

(2) If the 90° turn to the right on first encountering a beam takes the plane deeper into the opposite quadrant, instead of back to the beam, the ship passed to the left of the station, and the left hand of the two possible beams is identified. In this case a standard rate turn of 270° is made to the left. This new heading is held until the far edge of the beam is encountered. The right-hand edge is then bracketed down and followed to the station. (See fig. 35.)

b. How it is done.—(1) As soon as the signals are heard, check the identification signals to be sure which station is being received. Then listen for a background from the other quadrant. If only a clear A or N is heard, turn the volume up to an uncomfortably loud

level and note whether any background can best be detected during identification signals. If a background can be heard, remember the fact and turn the volume down again to as low a level as can be clearly heard and understood. With as little loss of time as practical, a standard rate turn should be made to a heading 90° to the average bisector of the two possible quadrants. If a background was present at the start of the problem, note whether it is growing louder or disappearing. If the background was noted at first only when the volume

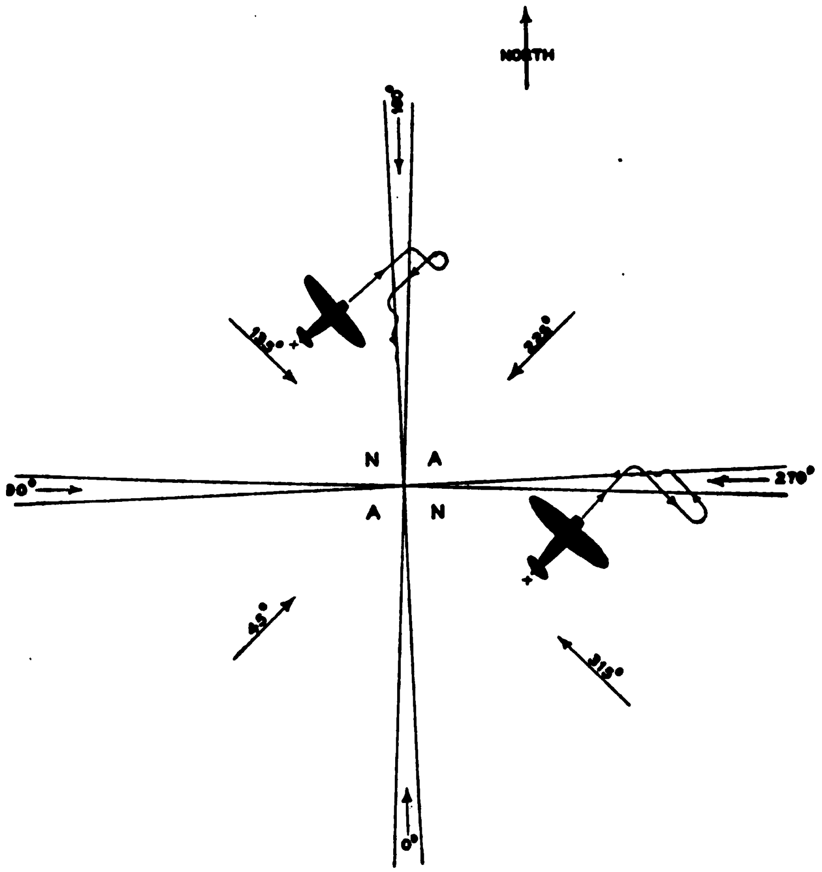


FIGURE 35.

was turned to a high level, the volume should be again turned up after 2 or 3 minutes and the increase or decrease of background noted. If the background was present and is fading it is obvious that the ship is going away from the nearest beam, and a 180° standard rate turn should be made to a heading which is the reciprocal of the previous one but still perpendicular to the average bisector. This heading should then be held until a beam is intersected.

(2) If no background was noted at the start of the problem, the first heading perpendicular to the average bisector should be held until a beam is intersected. Do not change course merely on a suspicion or assumption that there might have been a background. In-

spection of figure 35 will show that starting at X two of the four beams (the west and south legs) cannot possibly be intercepted, as they are behind. The only problem remaining is which of the two beams in front (the north or the east) will be encountered. The heading is held until a beam is crossed. The 90° identifying turn to the right is started on the first opposite off-course letter heard. While it takes a little longer to ride on through the beam to the opposite side before turning, it will tend to eliminate confusion resulting from trying to work an orientation problem on a false or multiple beam.

(3) After completing the 90° identifying turn to the right the heading is held and the signal change noted. If the problem started in an N quadrant, an A will be heard after passing through the beam. If this A becomes increasingly distinct after the 90° turn is made the quadrant and beam are definitely identified. Inspection of figure 35 will show that if the plane had started in the other N quadrant the new heading, after the 90° turn, would have taken the plane back through the beam and back into the N, thus definitely identifying the (in this case) east leg.

(4) After the beam is definitely identified, orientation is accomplished and finished. The remainder of the problem is simply a matter of getting on the right-hand edge of the beam and following it to the station. Experience has shown that the most practical way to do this is as illustrated in figure 35. A simple rule to remember is that when the maneuver leads from "like to like" (from an A back into an A or N back into an N) turn left 270°. It should be noted that this results in the turn back to the beam always being made away from the station, thus allowing more room in which to bracket the beam and get squared away before crossing over the station.

(5) When the identifying turn brings the ship back to the on-course the identification is definite, but the heading should be held for not less than a minute after reentering the beam before making the 180° turn, so that the turn may be completed before arriving back at the right-hand edge of the beam. This is particularly important with beginners in range flying, as they are very likely not to notice the change in signal while concentrating on making the turn, and will pass out of the beam without being aware of it. By allowing room to complete the turn the student is permitted to do one thing at a time, and so is much less likely to become confused. When going from "like to like" the 270° turn should be started as soon as identification of the leg is definite. The sooner this turn is started the better the results will be. Delaying this turn results sometimes in getting back to the beam too close to the station. (See fig. 36.) After com-

pleting the 180° or 270° turn, the heading is held until the far side of the beam is reached. As soon as the first off-course signal is heard, the right-hand edge of the beam should be bracketed down in the approved manner as previously described.

c. Advantages.—The 90° system is almost entirely mechanical and so can be learned quite easily. For this reason it makes a good starting point for the beginner in radio orientation. It has a further

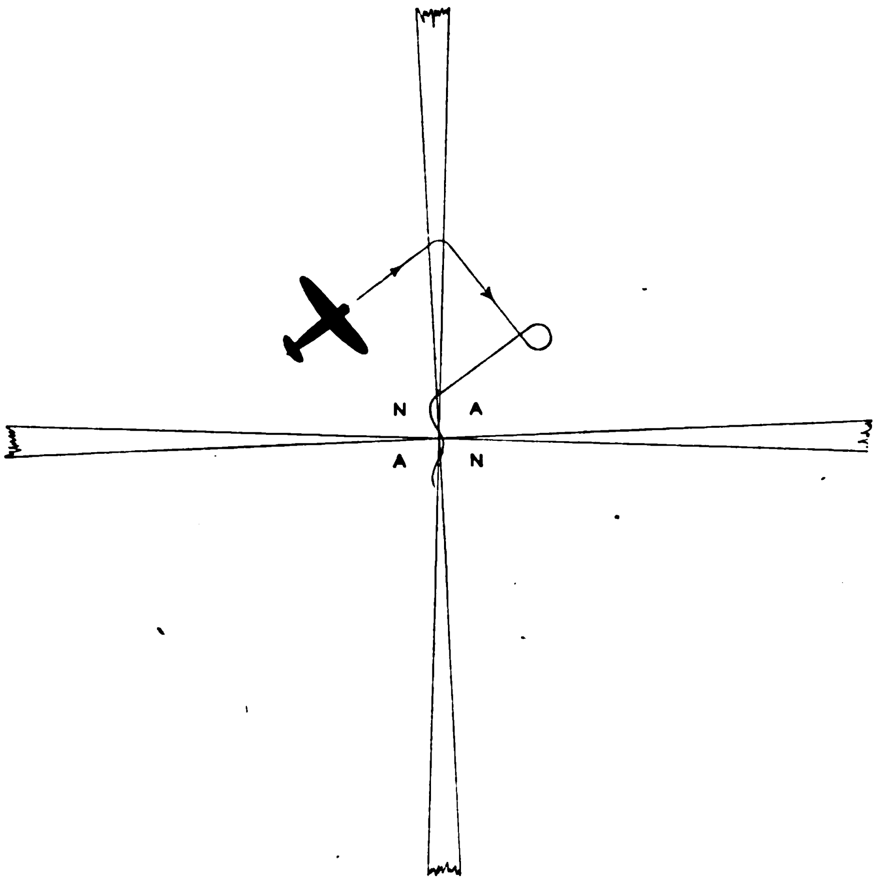


FIGURE 36.

distinct advantage of not depending for its success on changes in signal strength. It can, therefore, be used successfully on range stations where false fades and builds in signal strength are prevalent to an extent that would prevent the use of any fade-out system.

d. Disadvantages.—(1) The time required to complete a problem and reach the station is, in general, considerably longer when using this system than with most others. The system cannot be depended on if the on-courses of the radio range station are more than a few degrees from 90° apart. This statement applies equally to any system that utilizes a 90° turn to identify the beam, with one exception which will be covered later.

(2) Figures 37 and 38 illustrate two examples of the effect of a strong wind on the 90° system. In connection with this it should be borne in mind that during bad weather it is frequently impossible to

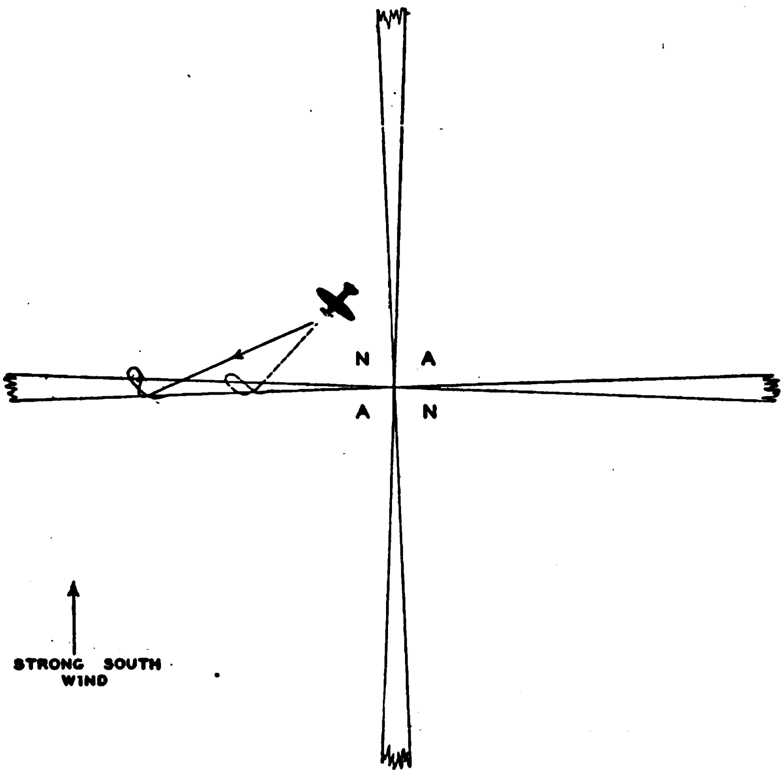


FIGURE 37.

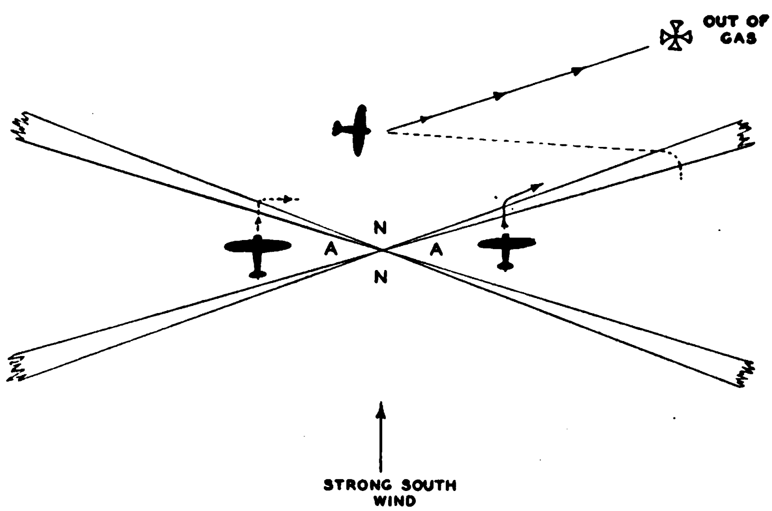


FIGURE 38.

obtain "winds aloft" reports. It should also be strongly borne in mind that the most frequent reason for a pilot becoming lost is the existence of strong, unpredicted winds at flight altitudes.

(3) Figure 37 shows the effect of a strong wind on the 90° system even on a "square" station. It will be seen that while the problem was eventually completed a considerable length of time was required. It should be noted that at a great distance from the station it would be easily possible to run out of range of the station before reaching the beam. Figure 38 illustrates the result of attempting to use this system on a squeezed or scissor station. The dotted line shows the track the pilot would think he was making, and the solid line shows the actual results. In the open quadrant the beam would never be intersected. In the narrow quadrant, having drifted into the N the pilot would believe himself to be on the northwest leg instead of the northeast, thus receiving false information that would be worse than none at all. In this case if the pilot succeeded in getting on the leg, he would undoubtedly follow it away from the station and eventually run out of gas. Sure, "he should check the fade." But this is the 90° system being used, the pilot thinks he is on the northwest leg because of drifting into the N (remember, he doesn't know about the drift), the compass heading which keeps him on the beam is approximately that of the inbound bearing of the northwest leg, he has an A on his right, and he is convinced he is on that northwest leg. When the radio fades he will be more likely to blame it on the battery or the crew chief than to suspect that he is definitely wrong.

(4) There are enough conditions under which the 90° system will not work to make it obvious that other systems must be learned.

e. Trainer instruction.—(1) In teaching the 90° system of orientation a chart of a square type radio range should be selected. The recorder should be placed with the inking wheel approximately 7 or 8 minutes from the radio station. It is desirable also at the start of a problem to have the inking wheel located in the edge of the bisignal zone. With the recorder properly lined up with the trainer and located as indicated, the student should be required to do a standard rate turn. In the meantime the trainer radio volume control and beamshift control are set in their proper position as indicated by the position of the recorder inking wheel. After the student has made a complete turn, the radio range should be turned on. Upon hearing the radio signals the student should recover from the turn and proceed to orientate himself. Since the student is again starting a procedure which is new to him, the signals should be exaggerated as was done in beam bracketing. As soon as the student deviates from the prescribed procedure the instructor should cut in with the microphone and straighten him out. Do not let him wander.

(2) It is a characteristic trait in nearly all students that when they first start listening to and concentrating on radio range signals and

orientation procedure they forget to keep a close watch on their instruments. The result is that students who have been doing excellent basic instrument flying will become erratic and careless about air speed and altitude. The instructor, therefore, must be particularly alert during the early stages of radio orientation to prevent the student from falling into bad habits which he may afterward never be able to lose.

(3) It is usually not desirable to work more than three orientation problems on the same chart. More than this number of problems on one sheet will track up the beams and make the chart difficult to follow. Before each successive problem is given to the student the instructor should check his previous charts. If one problem results in a 180° turn after identifying the leg, the next problem should be so set up that it will result in a 270° turn. If one student has to do several 90° method problems before mastering the system, care should be taken not to alternate the setting up of the problem in such a way that the student is able to anticipate or guess his position.

(4) Upon the completion of each problem the chart should be marked with the student's name, the date, and the instructor's name, and then filed for future reference.

(5) To demonstrate the effect of a strong side wind on the problem use the Fort Wayne instrument flying trainer chart. Start the problem in the west A quadrant and apply an easterly wind from 105° (10.5 on the wind direction dial). Extreme drift will result if the problem is flown at an indicated air speed of 120 mph and a 60 mph wind is applied from that direction. In most cases smaller drift angles will be more realistic and the problem should be flown at an indicated air speed of 160 mph. A wind of from 20 to 30 mph should be applied. The same problem may be set up on any square type radio range and in any quadrant, if it is remembered that maximum drift results at any given heading if the wind is at right angles to the direction of flight. Since in the 90° method the perpendicular to the average bisector is flown, it is only necessary to apply a wind from the direction indicated by that bisector.

82. True fade-out system.—*a. Basis.*—(1) The basis for the true fade-out system is exceedingly simple. When the radio range signals are received, turn to a heading parallel to the average bisector of the two possible quadrants. Turn the radio volume as low as possible consistent with clear reception. Hold the heading for not less than 5 minutes. If the signal strength is fading, turn 180° and hold the heading until a beam is intersected. If the signal strength increases on the first bisector heading, continue until a beam is crossed.

(2) Upon reaching a beam fly through it and on the first opposite

off-course signal turn left and bracket the beam in the usual manner as described under beam bracketing. Recheck for the fade or build. If the signal strength is increasing, continue on to the station. If it is fading do a procedure turn-around and continue to the station. (See fig. 39.)

b. How it is done.—(1) Upon starting the problem, turn the radio volume as low as possible and still read the signals. This is important as the lower the volume the easier it is to detect small changes in volume, and the less time will be required to complete the problem. Turn to the nearest of the two average bisector headings of the quadrant being received. (In certain cases it is desirable to turn to a certain one of the two possible headings. This will be covered later.) Hold this heading until there has been a definite change in volume. If the signal is building, continue until a beam is intersected. If the signal strength appears to be fading, make sure that it is really fading before assuming the station is behind and a 180° turn in order. False fades sometimes occur, and a fade over a period of less than 5 minutes should not be accepted. If over mountainous country it is advisable to make a second 5-minute check of the fading before turning around. During such a 10-minute test small fades and increases may have occurred, but the average volume is what must be considered. It is better to spend a few extra minutes at this point

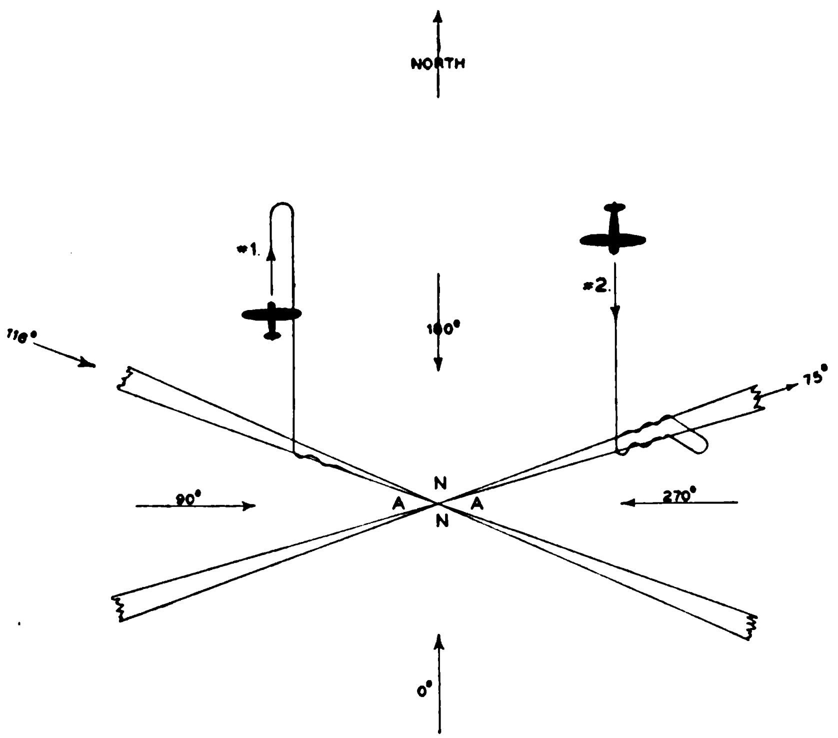


FIGURE 39.

making sure of the facts than to turn too early and then worry whether the signal actually had been fading and perhaps be led into turning around again and possibly winding up by becoming hopelessly confused. It is a peculiar fact that after a fade has been proved and a turn made so the pilot is headed toward the station, he will usually need to fly two to three times as far toward the station before he can recognize the increase in signal strength as he had to fly away to get the fade. This failure to be able to recognize the build in signal strength has worried many pilots into turning away from the station and wasting valuable time reworking the problem. Make sure of a fade before turning around and then do not worry if the increase in volume does not occur as soon as expected.

(2) The success of this system depends on close judgment of signal strength, not signal characteristics. In a wide open quadrant the signal characteristics can be of some aid. If at the start of the problem a background was heard and this background faded it would appear to indicate that the plane is going away from the station. This cannot be depended on, however, except in a wide quadrant and even then should be viewed with suspicion. (See fig. 40.) The dotted lines indicate the track the airplane would make in still air; the solid line, what occurs with a strong cross wind. In position No. 1 the plane is properly headed toward the station but a cross wind drifts in out of the background (indicated by the dashed line). Signal strength will be increasing properly but the background fades out entirely. Many a pilot has been known to "bite" on this one and turn away from the station. In position No. 2 it will be seen that while perhaps possible, a great amount of drift would be required to drift the ship out of the background while headed toward the station. Therefore, if in an open quadrant and the background faded it would be probable that the station is behind, but the build or fade should also be checked.

(3) Upon reaching a beam, fly through it and on the opposite side turn left and bracket the beam edge. Do not assume which leg will be intersected. Such an assumption, once planted in the mind, is difficult to get rid of in the 50 percent of the cases where it is wrong. Follow the simple rules and bracket the beam without worrying about which one it is.

(4) After the brackets have been narrowed down to only a few degrees, turn the volume down and check for fade or build just as was done in identifying the sector. If the volume increases, the leg is identified as the one which was on the right of the station as the bisector was being flown toward the station. If the volume fades,

the leg is identified as the one on the left and the plane as going away from the station. Do a procedure turn-around and follow the right-hand edge to the station. Do not at any time compare the compass heading with the published bearings of a beam and, if they happen to agree approximately, be fooled into thinking the beam is definitely identified.

(5) To illustrate the reason for the above refer to figure 39. The pilot naturally does not know whether he is in position No. 1 or No. 2. He has no way of knowing which beam he is going to intersect.

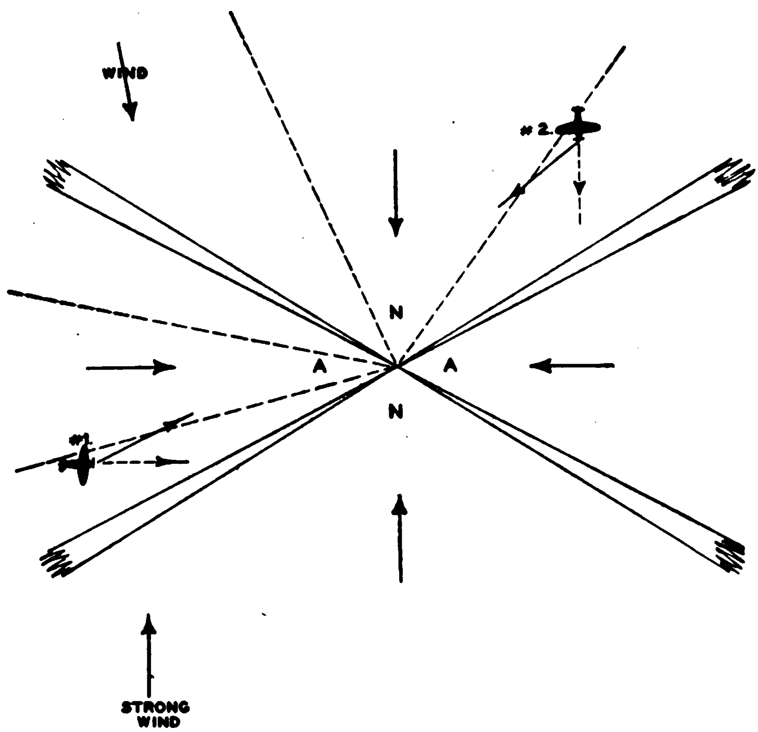


FIGURE 40.

Assume he is at No. 1 and has a strong north wind. When he intersects the beam he turns left and brackets it. He finds that to stay on the beam he must hold a heading of approximately 75°. He does not know about the drift. The compass heading agrees with the published beam bearing and he has an A on his right, so obviously (he thinks) he is on the northeast leg and turns around. Suppose he has been in position No. 2 with a strong south wind. After bracketing the beam he finds it necessary to hold a heading of approximately 115° to stay on course. Comparing this compass heading with the published beam bearing he assumes he is on the northwest leg and is probably quite happy about it all. The chances are excellent that he will

be planning the things he is going to say to somebody about the way his radio keeps fading out long before he realizes just who is wrong.

(6) The leg can be identified. In the example above while following the beam with an A on the right and the signal fading (going away from the station), the ship could only be on the northeast leg. The only other position with an A on the right and going away from the station would be on the southwest leg. Approaching from the north quadrant (approaching the station on the southerly bisector heading) this leg would not be intersected.

(7) As was previously mentioned, it is sometimes desirable to choose a certain one of the two possible average bisector headings. For example, if the pilot received an A and his map shows that the west A sector extends out over a lake, it is advisable to select the easterly bisector heading so that if he is in the west sector he will be flying toward land. When using a station which has a crowfoot pattern it is advisable to choose the inbound bisector heading of the largest sector. The rate of change of signal strength will be slow in such a large sector. If the pilot actually is in that open quadrant, the several minutes spent proving the fade will be taking him toward the station. In a crowfoot pattern, the bisectors of each quadrant differ considerably from the average bisector. On such a station it is advisable, after identifying the sector, to turn to the bisector of that particular quadrant.

c. Advantages.—The system will work on any station pattern (square, scissor, etc.). It is not appreciably affected by drift. In most cases it can be completed in considerable less time than the 90° system. It is the only range orientation system that can be depended on in wide-open quadrants.

d. Disadvantages.—Without considerable practice it is difficult for the pilot to recognize small changes in signal strength. During heavy static it is difficult for even experienced instrument pilots to recognize the changes in a reasonable time. The system cannot be depended on in some territories where mountains, ore deposits, etc., cause false fading over wide areas.

e. Trainer instruction.—(1) In teaching the true fade-out system of orientation a scissor station pattern should be selected. The recorder should then be placed in one or the other of the large open sectors. It is desirable about two-thirds of the time to select the position for the inking wheel so that after the student has intersected the beam and bracketed it he will be going away from the station. This will give him further practice in checking the fade and also in maneuvering on the beam. Particular care must be taken by the instructor

to insure that the student is not identifying the beam by the compass heading. It is not sufficient to ask the student how he identified the beam; rather, a condition should be created in which identification of the beam by compass heading alone will result in a wrong identification. In placing the recorder for true fade-out problems, it should be placed far enough from the center of the sector so that the student will encounter a beam far enough from the station to have plenty of room to bracket it down. Throughout this system or in any other system involving the student's checking a fade, it is essential that the volume control be handled smoothly and with extreme care in order to give the student the right kind of information.

(2) To demonstrate the fact that beams of radio ranges should not be identified by their published bearings, use the Chattanooga instrument flying trainer chart. Start the problem in the east A quadrant, setting the recorder so that the southeast on-course will be intercepted about 10 miles from the station. Apply a wind: 260°, 60 mph. After the student has intercepted the southeast on-course, made his left turn, and bracketed the beam, the heading necessary to maintain the outbound edge of the beam will be approximately 182°. This heading is halfway between 203°, the published inbound bearing of the northeast course, and 160°, the outbound bearing of the southeast beam. It should be obvious to the student that the heading of 182° on which he is now flying does not tell him which of the two possible beams he has intersected. The recorder may also be set to intercept the northeast course; in this case the wind must be applied from 80° to produce a heading of approximately 185° when following the northeast beam toward the station.

83. Parallel system.—*a. Basis.*—The basis for the parallel system is very simple and similar to the true fade-out system. When the range signals are received, turn to a heading parallel to the average bisector of the quadrant signal being received. Turn the volume as low as can be clearly heard and check, over a period of at least 5 minutes, whether the signal strength is increasing or decreasing. For example, assume an N is being received from the station in figure 41. The average bisector is either north or south. Assume the south heading is selected and the volume fades. The plane is, then, in the south quadrant. If on the south heading and the volume builds, the plane (in this example) is in the north quadrant. If the volume fades, turn to the reciprocal heading and fly toward the station for the same length of time as was flown away from it while checking the fade. Then assume a heading parallel to one of the two beams that are in front in order to intersect the other beam. (See fig. 41.) On intersecting

the beam, turn toward the station and bracket the beam in the approved manner.

b. Advantages.—The system is easy to remember. Under certain conditions it simplifies identifying which leg is intercepted. In conditions under which it will work, it is a little faster than the true fade-out. Under workable conditions, it allows the pilot to choose which leg he will intercept.

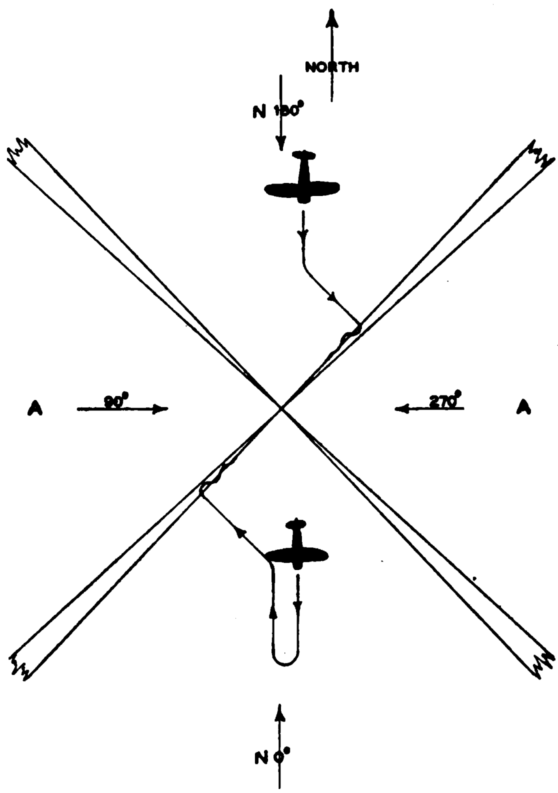


FIGURE 41.

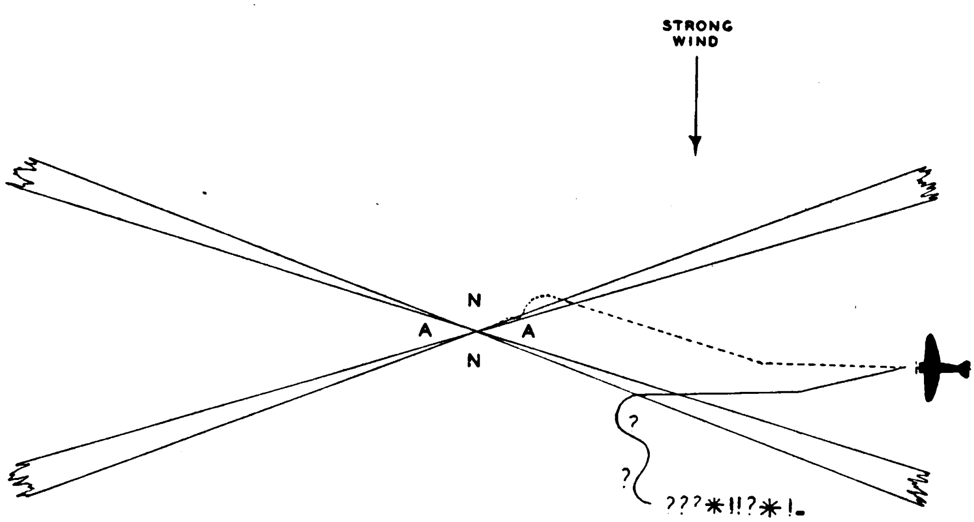


FIGURE 42.

c. Disadvantages.—The system is easily disrupted by drift and cannot be relied upon under conditions of unknown drift except on stations that are practically square. Figures 42 and 43 illustrate the result of attempting to use the method on a scissors type range. The dotted lines indicate the intended track and the solid lines the actual track when affected by drift.

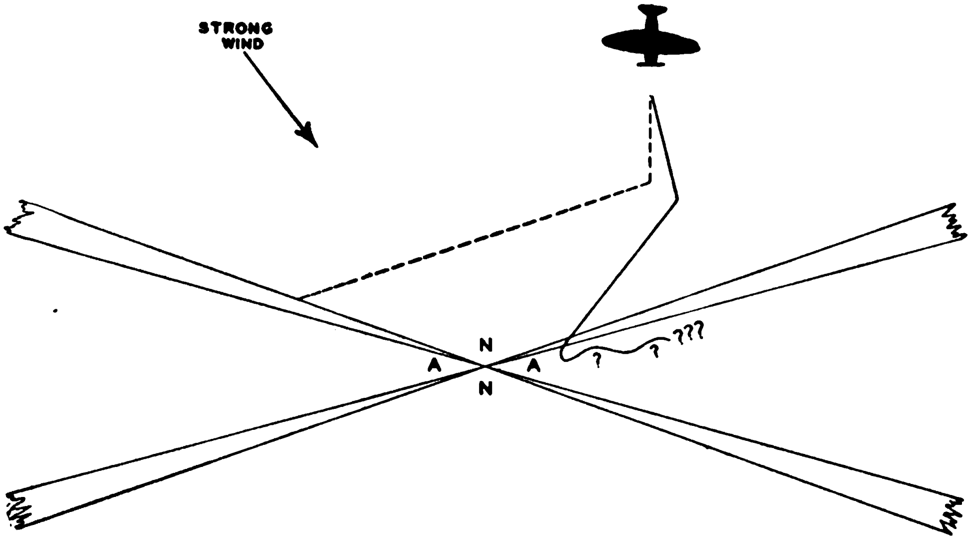


FIGURE 43.

84. Parallel-perpendicular system.—*a. Basis.*—The basis of this system is similar to the parallel system. The quadrant is identified in the same manner as in the parallel and the true fade-out. Then, instead of being influenced by the beam it is not desired to hit, a heading is taken directly toward the desired beam (perpendicular to it). Upon crossing the beam a turn of 45° is made away from the station. This heading is then held for from 45 seconds to a minute, then a turn of 180° is made also away from the station. (See fig. 44.) This heading brings the plane back to the beam at a relatively easy angle from which to bracket down in the usual approved manner headed toward the station. All turns are at a standard rate.

b. Advantages.—This method may be depended on except in an open quadrant (beams more than 90°). In a squeezed quadrant it will stand as much drift as any system. It has all advantages of the parallel system plus being workable in a squeezed quadrant.

c. Disadvantages.—The method cannot be depended on in a quadrant where the beams are more than 90° apart. An extra turn is used in turning to get on to the beam. If sufficiently far from the station to allow room to bracket, the 45° and 180° turn away from the station may be eliminated, however, and a turn made toward the station fol-

lowed by the usual bracketing. Figure 45 illustrates why the system will not work in an open quadrant.

d. Trainer instruction.—In teaching these systems, a scissor station should be selected as was done with the true fade-out. The recorder, however, in this case should be placed in one of the narrow quadrants (bearing in mind that neither of these systems can be depended on in

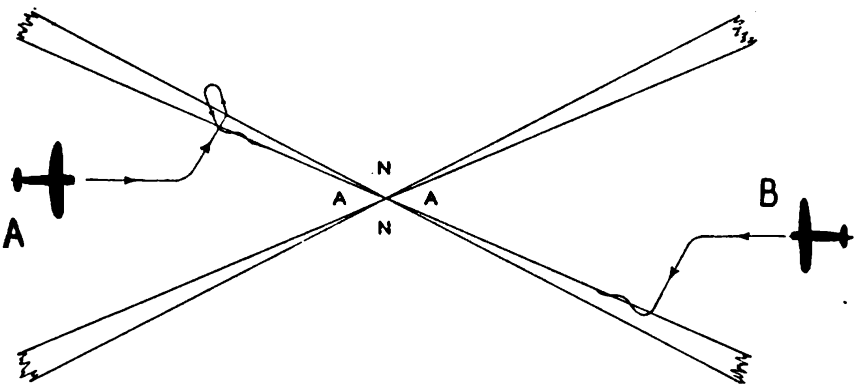


FIGURE 44.

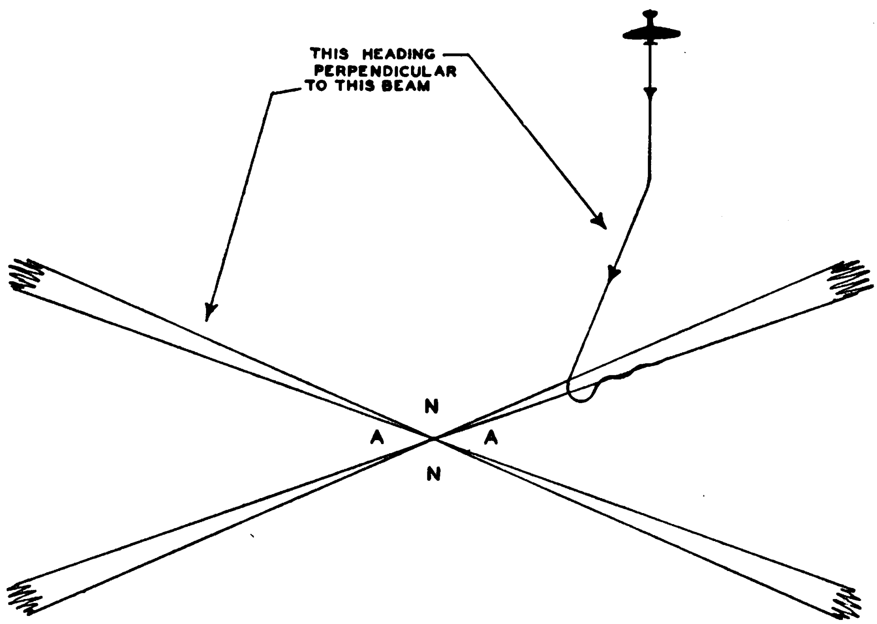


FIGURE 45.

an open quadrant). If a doubtful student should insist that the parallel system will work in an open sector, the instructor should at the start of the problem place the inking wheel of the recorder well out in one of the open sectors and apply drift away from the station. Under this condition ample proof can be shown of what happens to the parallel system. To demonstrate that the parallel-perpendicular system will not work in a wide-open sector, the recorder should be placed far

enough to one side of the sector so that the perpendicular heading will encounter the wrong beam.

e. To demonstrate the effect of drift on the parallel system when used in a squeezed sector of a radio range under conditions of extreme drift, use the Chattanooga instrument flying trainer chart. Start the problem in the south N quadrant. After the student has checked the fade and is flying toward the station on a heading parallel to the 23° beam, apply an easterly wind: 115°, 60 mph. If the student turns to a heading of 340°, parallel to the southeast on-course, apply a westerly wind: 250°, 60 mph.

85. Fade-out 90° system.—*a. Basis.*—The quadrant is identified by the fade-out and parallel systems. The inbound bisector heading is flown until a beam is intersected. The beam is crossed and upon receiving the first opposite off-course signal a 90° turn is made. (This turn may be made either way without affecting the efficiency of the system, but it is recommended that it be made to the right for the sake of standardization.) When headed toward the station on the bisector heading there is a beam on the left and one on the right. If the 90° turn to the right brings the ship back into the same quadrant, the left beam was the one intercepted. If the identifying turn takes the ship deeper into the opposite quadrant, the beam intercepted was the one on the right. (See fig. 46.) As soon as the beam is identified a turn to the right (away from the station) is made to get back to the beam. If the beam on the right was intercepted, the turn should be of 180°; if the left beam, 270°.

b. Advantages.—When it will work it is quicker and easier than some other systems. Its best use is in a squeezed sector to avoid having to bracket the beam and then identify it by the fade as in the true fade-out.

c. Disadvantages.—It cannot be depended upon in an open quadrant. (See fig. 47.) Quadrant identification is difficult in sections where false fades or builds in signal strength are prevalent. It has most of the disadvantages of both the 90° system and the true fade-out system. It should be recommended for use only in a squeezed quadrant.

d. Trainer instruction.—This system may be taught on any station pattern but should never be attempted in a wide-open sector. If it becomes necessary to demonstrate that it will not work in a wide-open sector, place the recorder in such an open sector with a strong drift away from the station. That part of the sector should be selected which will permit the recorder to intersect that beam which is on the pilot's left as he approaches the station. Under these conditions the

plane will be drifted back across the beam, and the pilot will receive misinformation to the effect that he is on the other beam.

86. Unknown station system.—*a. Basis.*—The basis of the system is simple. It is designed for use where a map of the station being received is not available and where nothing is known about the pattern

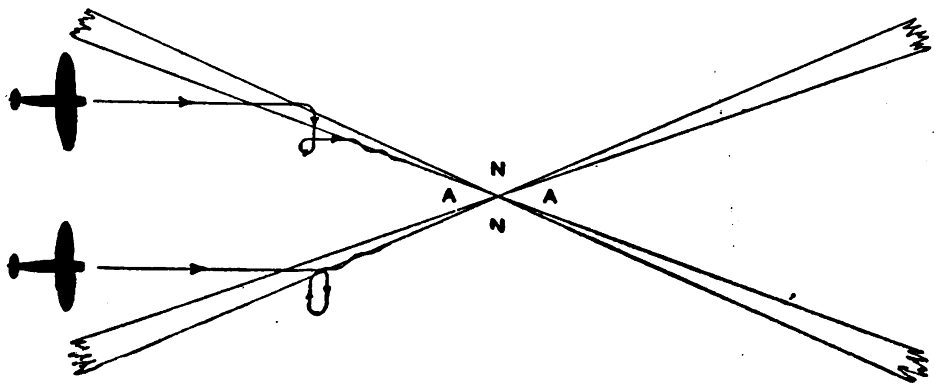


FIGURE 46.

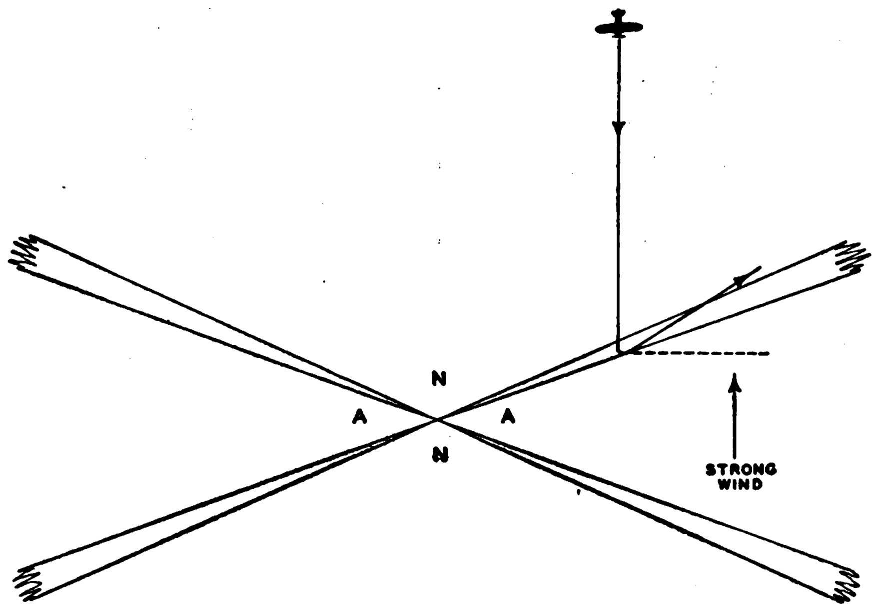


FIGURE 47.

of the beams. It is an adaptation of the true fade-out system, and the average bisector heading is flown and checked for a fade or build. Since the station pattern is now known, the approximate average of all the average bisectors is flown. This heading is 80° in an A and 350° in an N or their reciprocals.

b. How it is done.—(1) When the station is tuned in, turn to the proper heading for the letter being received. Note whether there is a background and turn the volume low as in the fade-out system. Check for a fade or build over a period of at least 5 minutes. If the

background fades pay especial attention to signal strength, and if the strength is either fading or remaining constant turn 180°, as it is evident the nearest beam is being left behind. If, however, the

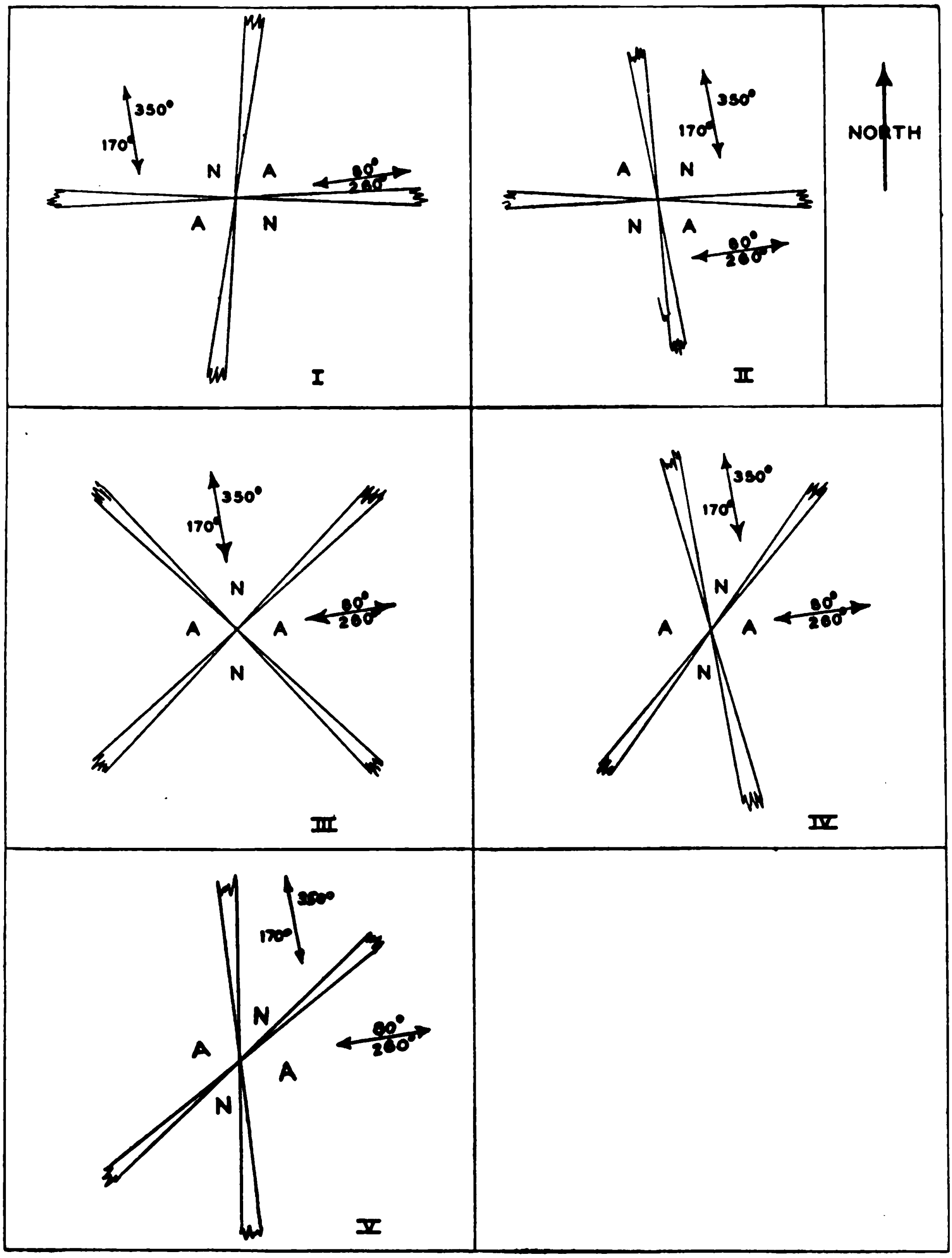


FIGURE 48.

volume increases, continue until a beam is intersected. If there is no change in signal strength or if there is no change in the back-

ground, after several minutes of flight turn 90° and recheck for fade or build.

(2) Figure 48 illustrates that, regardless of station pattern, one of the "average of all bisector" headings points toward a beam. In still air this is theoretically true except when at a considerable distance from the station and under certain conditions as shown in figure 49. In this case a fade results on either bisector heading for the N quadrant. Actually, however, this fade or build would be so slow under the condi-

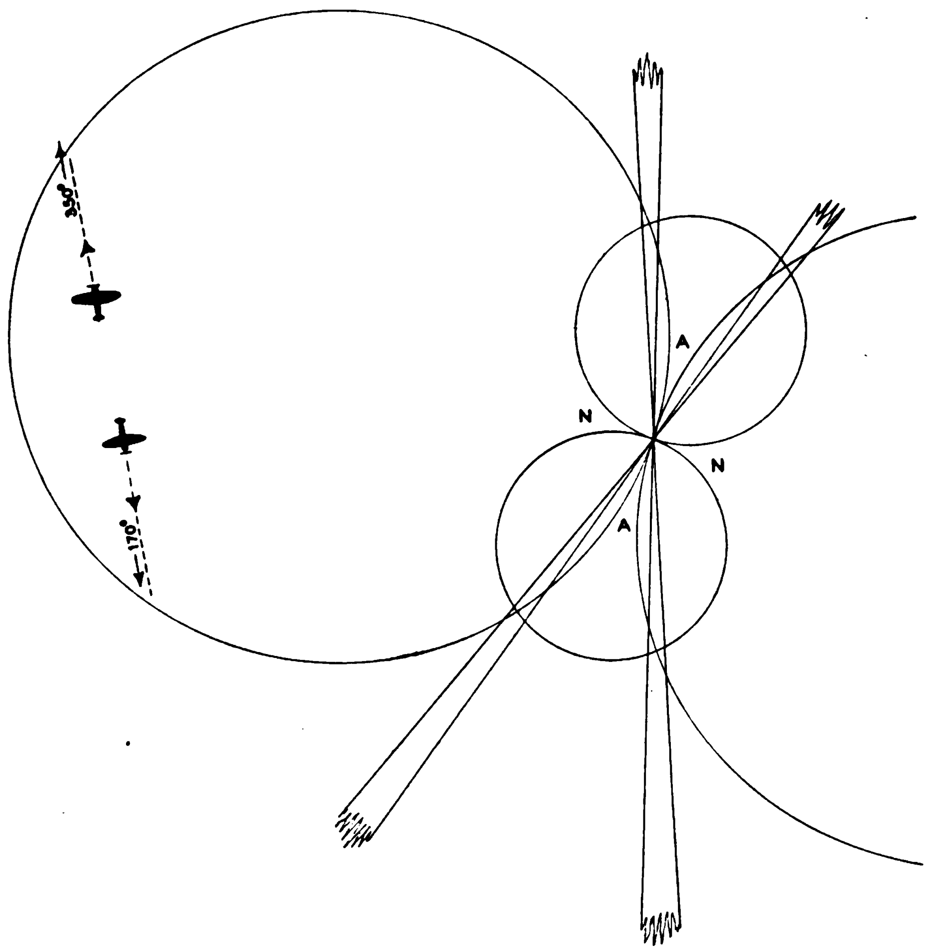


FIGURE 49.

tion illustrated as to be unnoticeable unless the heading were flown for a long time, and as mentioned above a 90° turn should be made and the build or fade rechecked. If fading, turn 180° and continue as long as the signal strength or the background, if any, is definitely increasing. If after a half hour or more of flight the signal strength again starts to decrease (without a definite and steady build in background), another 90° turn should be made and the fade again checked. Again, if fading, turn 180° and continue as long as the signal strength or

background is definitely increasing. Simply stated, the system consists merely of flying into constantly increasing signal strength, turning 90° whenever necessary to accomplish it, until a beam is intercepted.

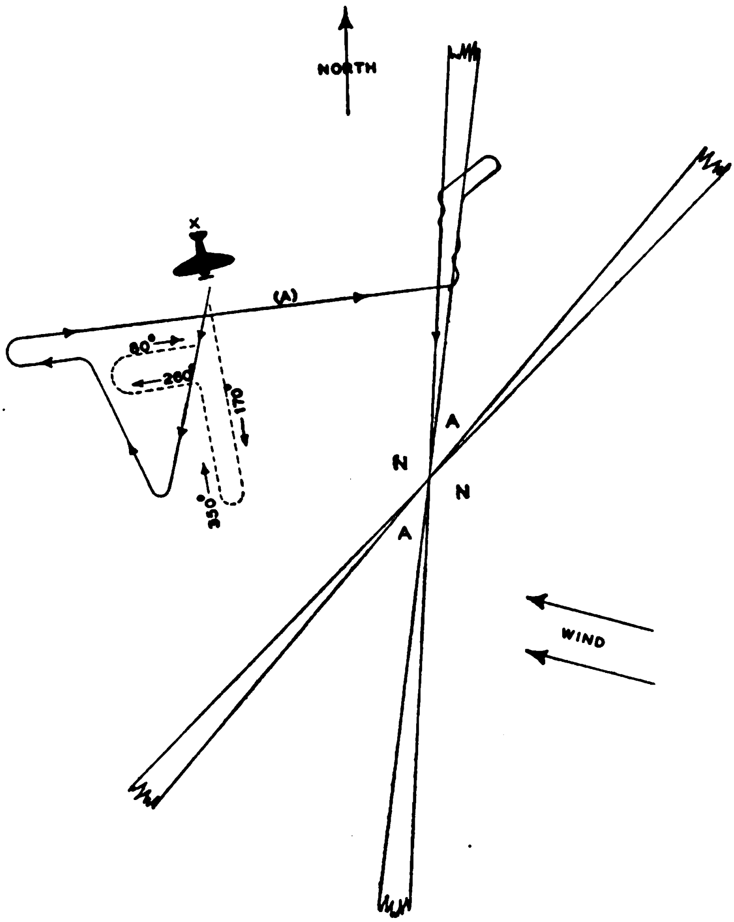


FIGURE 50.

(3) Figure 50 illustrates the effect of drift on this system. Starting at X the pilot elects to adopt the 170° heading (because it was nearest to the heading he happened to have when the radio was tuned in). Holding this heading for several minutes he hears a slow fade in signal strength. (While he is not actually getting farther from the station he is going away from the center of the field of greatest signal strength.) So he turns 180° and flies the 350° heading. Unknown to him, there is a strong drift away from the station. The dotted line indicates his headings and what would have been his track in still air. The solid line shows his actual track as a result of the drift. On this new heading, although slowly approaching the stronger field of strength, he is definitely getting farther from the station and again gets a fade. The pilot then turns 90° to the left to a heading of 260°. He gets a rapid fade this time as he is

going nearly straight away from the station and is pushed along by the tail wind. This is definite evidence, and the pilot turns 180° to the heading of 80° and holds it. The build is slow but continuous so the pilot continues on the heading of 80°. At point A the volume ceases to increase and starts to fade slowly but the pilot remembers the rule about turning up the volume and checking for a background. There is a background so he continues to hold the heading and notes that while the volume continues to decrease slightly the background is steadily building, indicating that he is approaching a beam.

(4) The heading is held until across the beam, and on the first opposite off-course signal the pilot turns left and brackets the beam in the customary approved manner. He then rechecks the fade, finds he is going away from the station, does a procedure turn-around, rebrackets the right-hand edge of the beam, and follows it to the station.

c. *Advantages.*—It provides the pilot with an emergency procedure in the event his map is lost or he has drifted over territory not covered by the maps. It will work in the majority of cases.

d. *Disadvantages.*—In most cases, the method requires much longer to work than other methods. It will not work in territory where false fading is prevalent. It requires extremely accurate judgment of signal strength on the part of the pilot. Though the method should be regarded only as an emergency system, it should be mastered, nevertheless.

87. Multistation system.—*a. General.*—While circumstances are not always such that this system can be used, in most instances it will supply considerable information and in many cases will definitely place the position within a very few miles. It consists of tuning the station it is desired to approach and noting the signal received, and then tuning various selected surrounding stations and noting the signals received from them. A set of conditions is frequently set up under which the ship could only be in a certain area.

b. *Method* (see fig. 51).—Starting at X (but not knowing where he is) the pilot tunes in the station he wishes to fly to (No. 1). He receives an N quadrant signal. He also hears a background but has no way of knowing which of the four beams he is adjacent to. Looking at his map he notes that a beam from station No. 2 lays practically over the station he is working on. He tunes in station No. 2 and hears an N with strong background. This definitely places him in the north N of station No. 1, as had he been in the south N he would have heard an A from No. 2. He now knows he is in the north N and near either the northwest or the northeast leg but does not know

which. Checking his map he notes that another station (No. 3) has one beam which cuts through the north N of his station so he tunes in that station. He receives an A with a strong background. This definitely places him somewhere within the dotted circle and the orientating was accomplished in the few minutes it took to tune in two extra stations. Knowing which beam he is close to he heads toward it, brackets it down, and follows the right-hand edge to the station.

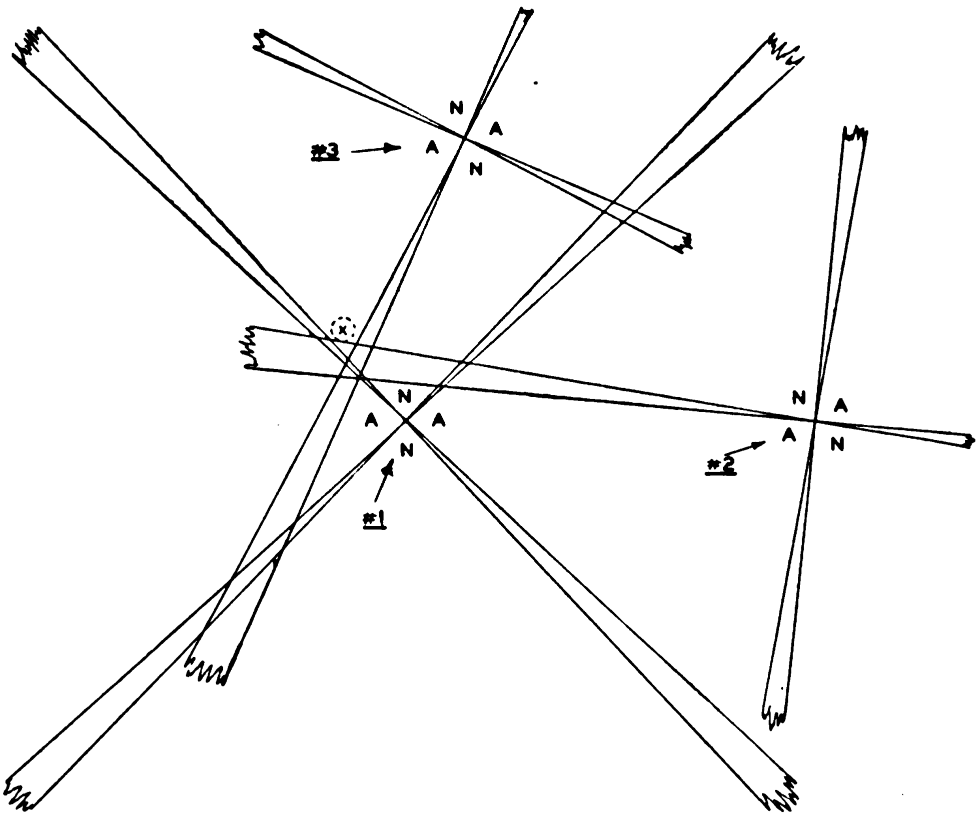


FIGURE 51.

a. Trainer instruction.—Select an advanced instrument flying trainer chart and give the student a radio facility chart for the same area. (The page covering the area should be taken from the Air Corps Radio Facility Charts and mounted on cardboard. The actual identification signals of the radio range stations to be used should be changed to correspond to the signals available on the trainer. The signals to be used should also be marked on the flying trainer chart to assist the instructor.) Have the student make one or two 360° turns. The student should then call for the stations he wishes to tune in on. The instructor should be extremely careful to give the appropriate signals when changing from one station to another. It is

advisable to keep the range-voice control on VOICE while making the changes, returning to RANGE only after the new station has been set up. On the C-5 trainer two stations may be concurrently operated. The student can tune from one station to the other and back exactly as in an aircraft, provided the instructor keeps the proper signals and signal strength set up on both stations. After the student has located himself he should proceed to the nearest station.

88. Lost on beam system.—*a. General.*—When the radio is turned on it occasionally happens that the ship is on-course, already on one of the four beams. This is somewhat disconcerting, and unless the pilot is already armed with a suitable method he will probably feel that he must somehow get away from the beam in order that he may find it again, and in so doing waste considerable valuable time. Orientation consists of three steps: find a beam, identify it, and follow it to the station. If already on a beam when the radio is turned on there remains only to identify it and follow it in. There are two methods—one is an adaptation of the fade-out and the other of the 90° system.

(1) *Lost on beam fade-out.*—On tuning in the radio and hearing a solid on-course, turn to the nearest bisector heading to the left. It may be any one of the four. Hold this heading until the edge of the beam is reached. (If the edge is not reached in 3 or 4 minutes, turn 90° to the left to the next bisector heading and hold it.) When the first off-course signal is heard start a standard rate turn to the left and bracket the beam in the approved manner. Turn the radio volume down and check for a fade or build in signal strength. If the signal is fading, do a procedure turn-around and continue to the station. Meanwhile, the beam is identified by the letter on the right, the increasing signal strength, and the general compass heading. (Remember, the compass heading means nothing without checking the fade or build.)

(2) *Lost on beam 90°* (good only on "square" stations).—On tuning in the radio and hearing the on-course signal, turn to the nearest one of the four bisector headings. On reaching the edge of the beam do a 90° turn to the right. This turn will bring the ship either back across the beam or take it deeper into the off-course. Whichever it does, considered with the bisector heading selected to run off the beam, will definitely identify the particular beam. (See fig. 52.) Say the bisector heading of northwest (315°) was selected, turned to and held to the edge of the beam, and the 90° right turn made. Note that the conditions are different for each beam. For example, if the ship went into an A and stayed in the A, the beam is identified as the east leg

as, starting with the 315° heading, these conditions cannot exist on any of the other legs. If the ship went into an A, then back into an N, the south leg is identified; if into an N and back into an A, it has to be the north leg.

b. Fade-out lost on beam method.—(1) *Advantages.*—The method will work on any station except where false fades are prevalent. It takes advantage of habits already formed and used in the fade-out

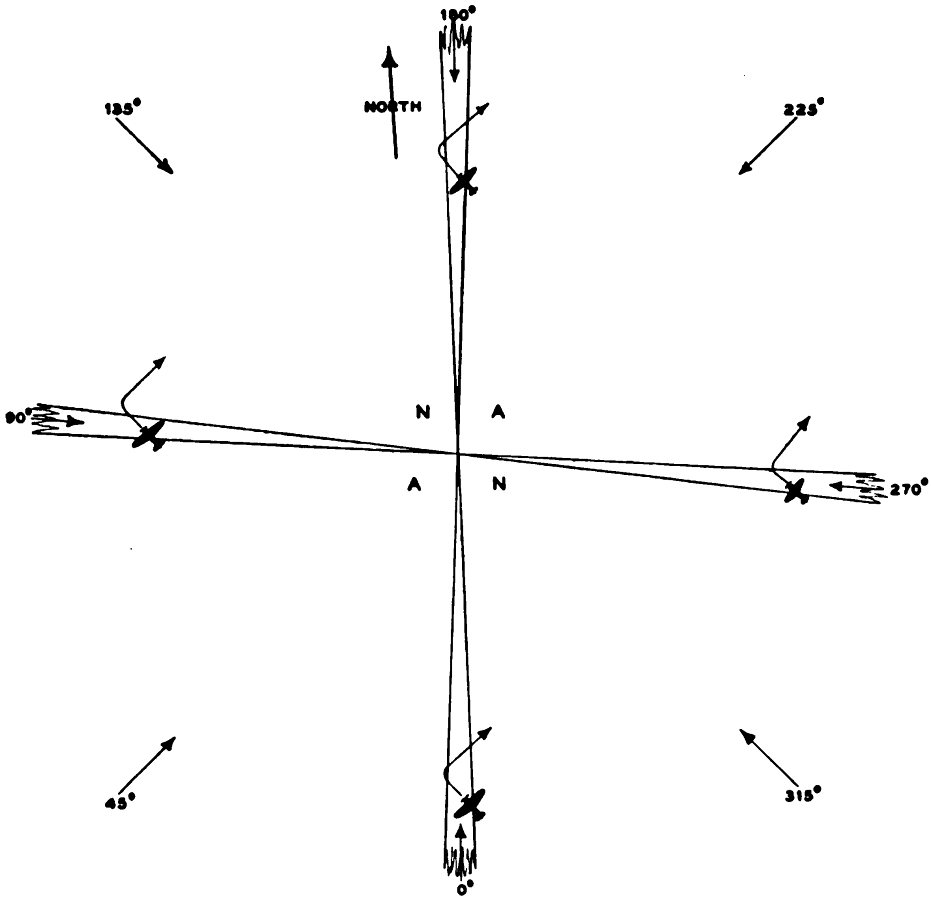


FIGURE 52.

system and in beam bracketing and so is easy to remember and nearly automatic.

(2) *Disadvantages.*—It will not work where bad fading exists. It takes more time to work than the 90° method.

c. 90° lost on beam method.—(1) *Advantages.*—The method is quick and positive where usable.

(2) *Disadvantages.*—It can be depended on only on a square station. It requires rapid and clear thinking on the part of the pilot.

d. Trainer instruction.—(1) The recorder should be placed at a point well out on the selected beam, on an appropriate instrument flying

trainer chart. Leave the recorder turned off until after the student has done his full rate turn and has recovered from it and has started a turn toward the proper heading.

(2) The problem can be done several times in a half-hour lesson, and the recorder should be set on a different beam for each attempt. The position relative to the center of the beam should also be varied so that in one case the student will get squared away on his new heading before reaching the beam edge, and in another case he will still be turning toward this heading when he runs out of the beam.

(3) In teaching and practicing this system, excessive time should not be wasted following the edge of the beam after it has been identified, since the purpose of the procedure is simply to identify the beam. When this has been accomplished the problem is over and a new one should be started without waste of time.

89. Close-in procedure.—*a. General.*—When in close proximity to the range station it is sometimes impossible to complete an orientation method, because while holding a heading or making a turn to prove the identity of a beam, another beam will be crossed and confusing information result. Consequently, when the rapid change of signals indicates that the station is close at hand, and an attempt proves that there is not room to work an ordinary system, another method should be resorted to. In fact, when one realizes that he is in the vicinity of the station, he knows where he is and does not need to orientate himself (since orientation is the business of finding one's position).

b. Methods.—There are two methods of close-in procedure, the parallel and the bisector methods.

(1) In the parallel method the ship is turned to the heading which parallels the outbound bearing of the beam on which it is desired to make the initial approach to the station. This heading is held and the changing signals ignored until a fade is obtained. The signal then received will tell which side of the beam the ship is on. A turn of 45° is then made toward the beam. This new heading is held until 45 seconds past the beam. A 180° turn away from the station is then made to get back to the beam. The beam is then bracketed down in the usual manner. (See fig. 53 ① and ②.)

(2) The bisector method is similar except the initial heading is that of one of the average bisectors. This heading is held until a fade is received and then a 90° turn is made toward the desired leg. This heading is held until the beam is crossed and then the same procedure is followed as in the parallel method. (See fig. 53 ③.)

c. Advantages.—Either method provides a quick, positive, and easy method of getting onto the desired beam when lost or confused near the station.

d. Disadvantages.—(1) *Parallel method.*—When working a station with two very narrow quadrants there is a possibility of a strong wind drifting the ship across the narrow quadrant. When the open quad-

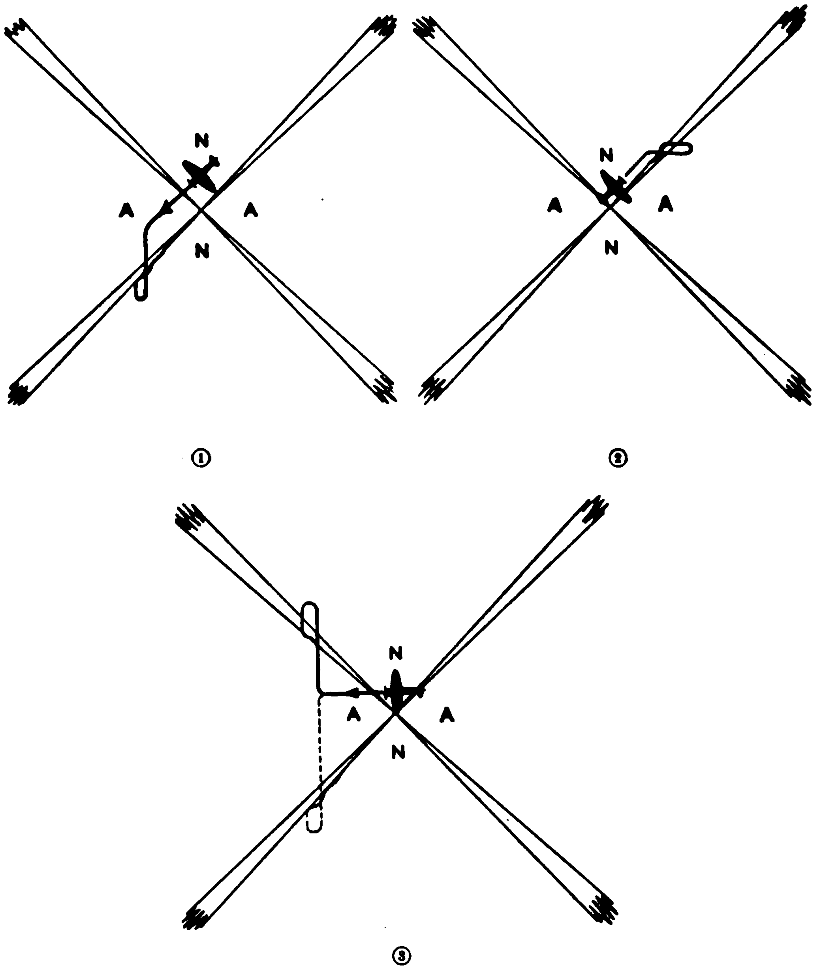


FIGURE 53.

rant signal is received the pilot cannot be sure which of the two quadrants he is in. This condition is, however, readily detected when the turn is made to get back to the beam. If the ship has drifted into the other quadrant the background will diminish rapidly.

(2) *Bisector.*—This method can be relied upon only on a square station. It takes slightly longer than the parallel method.

e. Trainer instruction.—In practicing this method the recorder should be placed within about 1 minute of the station, the switch left off, and the student instructed to do the full rate turn. When he hears the radio range come on, he should stop the turn and then immediately

start a standard rate turn to the outbound heading of the beam which passes over the field. As soon as he has proved the fade and turned around and crossed back over the station the problem is completed. At least two, usually three, of these procedures can be done in a 30-minute session.

90. Selection of proper procedure.—*a.* The foregoing methods and systems are not really separate systems at all. They are merely the parts that form radio range orientation. There are basically only two ways to identify a radio beam: by a 90° turn or by the change in signal strength, or a combination of both.

b. The pilot must have a clear understanding, however, of exactly under what conditions the basic steps or their various combinations will work, and the conditions under which they will not work. The foregoing outline of systems is merely a step by step presentation of orientation procedure, broken down to show the proper combination of the basic elements as applied to specific situations. When the various steps and systems have been thoroughly mastered, the student will have a complete picture of range orientation and will no longer need a system or a variety of them. He will execute the maneuver that common sense dictates for the particular set of conditions, and will know enough about orientations so he will not be tempted to depend on some short-cut or cure-all procedure under conditions when it will not work.

c. Obviously, if such a pilot finds it necessary to orientate on a scissor station and in an open quadrant, he will identify the sector by a fade or build; and after reaching a leg will identify it by again checking the fade or build. If he is in a squeezed sector of such a station he will identify the sector by signal strength, but he knows that after this is done the leg can be quickly identified by a 90° turn; or he will head directly toward a chosen leg if he desires to approach the station on that particular leg.

d. Stated briefly, after the pilot has mastered the preceding outline of orientation he will know enough about the entire subject and the limitations so that all he needs to do is to exercise common sense.

91. Let-down and instrument approach procedures.—*a. General.*—(1) Standard approved procedures are being published by commercial airlines, the CAA or Army Air Forces activities for all range stations where conditions make instrument let-down and approach practical.

(2) Although bearings, altitudes, and numerical values in general will vary at each station, procedures are standardized as far as practicable. Generally the following applies:

(*a*) Call the tower and ask for clearance to make standard approach. If cleared—

(*b*) Cross the cone of silence (station location marker) at the proper altitude (initial approach).

(*c*) Proceed out the on-course signal opposite to that crossing the airport.

(*d*) At the proper time turn 45° off course.

(*e*) Make 180° turn away from the station to return to on-course.

(*f*) Fly on-course to intercept cone, letting down to final approach altitude.

(*g*) Begin timing let-down to minimum altitude over the field.

b. Trainer instruction.—Approach or let-down procedure charts are furnished for the student's use when flying an approach problem on the corresponding instrument flying trainer charts. (See fig. 54.)

(1) *Initial approach.*—(*a*) In preparation for making an instrument let-down, the first time the student reaches the range station is referred to as the "initial approach." This approach may be made on any of the range courses unless otherwise specified in the procedure being used. The altitude shown on the charts for this portion of the problem is the safe minimum for instrument flight (other than let-down for landing) in the local area.

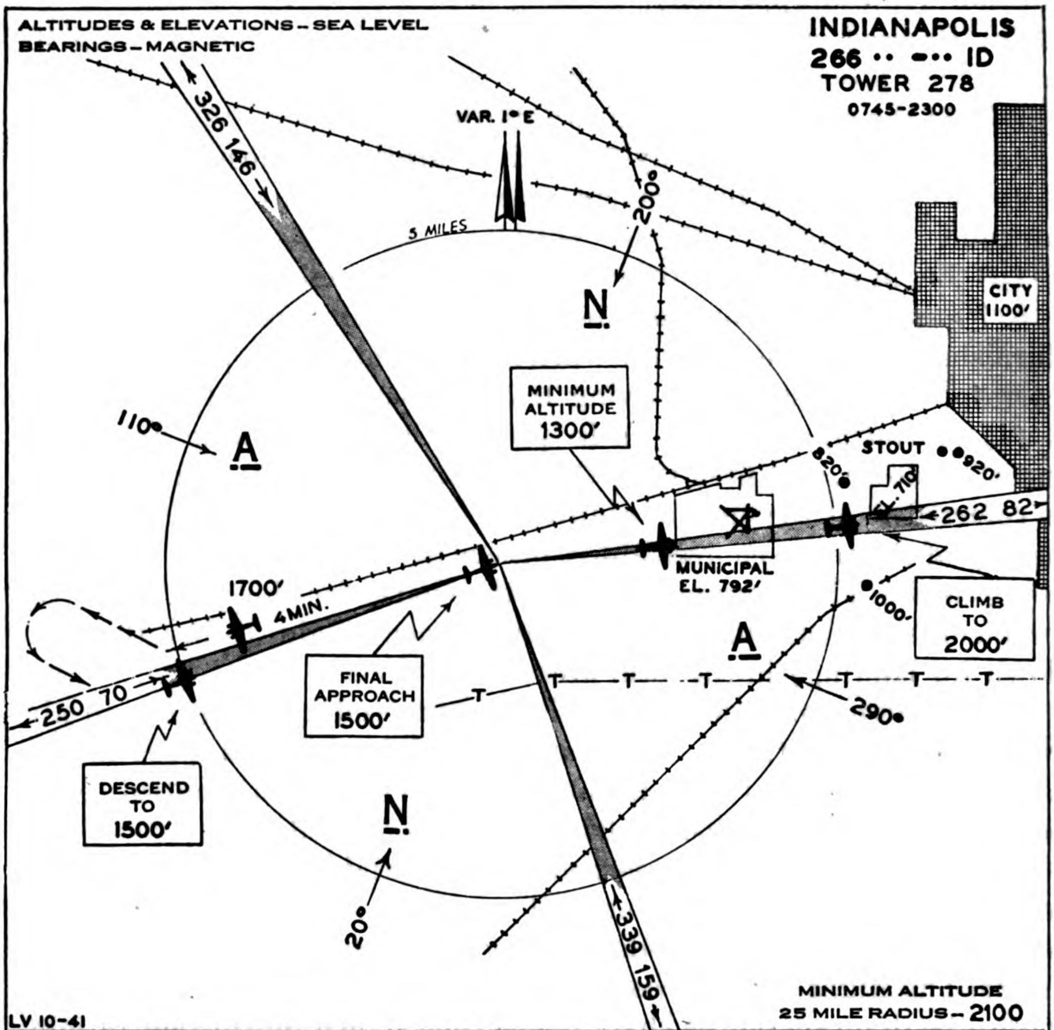
(*b*) In actual practice where flight is proceeding along a civil airway at a higher altitude than that specified for initial approach, permission must be secured from the proper airway traffic control center before descent from cruising altitude may be started.

(*c*) When the station is reached on the initial approach, a report is made by radio to that effect and all necessary information pertaining to the completion of the let-down is received from the ground station.

(*d*) The flight then proceeds out the proper range course according to the diagram on the chart. The time shown on this leg (4 minutes where local conditions permit) is sufficient to permit further descent when specified as well as to allow the pilot to bracket the beam, determine drift angle, and establish a gyro heading therefrom. Any descents necessary in this phase are to be performed at the rate of 300 feet per minute unless otherwise specified under "Remarks" on the chart.

(2) *Procedure turn.*—(*a*) Where local conditions permit, this turn is started to the right of the beam. In this case the course of flight is changed 45° to the right of the gyro heading previously established. Altitude and speed being held constant this new course is held for 1 minute, at which time a standard 180° left turn is made. The student holds this heading until the beam is again reached *and crossed*,

at which time he alters his course to follow the beam on-course back to the station. This turn is indicated on the approach charts by a series of arrows.



INITIAL APPROACH	2000	OVER CONE
PROCEDURE TURN	1700	4 MIN. FROM CONE ON SW LEG
FINAL APPROACH	1500	OVER CONE
MINIMUM ALTITUDE	1300	3.3 MILES FROM CONE

REMARKS STOUT FIELD CLOSED, CONSTRUCTION

TIME DISTANCE FROM CONE TO FIELD (3.3 MILES)

100 M.P.H.	110 M.P.H.	120 M.P.H.	130 M.P.H.	140 M.P.H.
1 MIN. 56 SEC.	1 MIN. 48 SEC.	1 MIN. 39 SEC.	1 MIN. 31 SEC.	1 MIN. 25 SEC.

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FIGURE 54.

(*b*) In cases where the procedure turn must be made on the opposite side of the beam, the arrows on the chart will indicate such necessity,

but timings and angles of course variations are the same. In any case, however, the 180° turn must be made "away from the station."

(3) *Final approach.*—(*a*) In returning to the range station, along the approach leg, those maneuvers required to bring the flight into a position for the final let-down compose the "final approach."

(*b*) The minimum altitude to which descent may be made on this phase of the procedure is indicated on the chart under "Descend to ______" as well as under "Final approach ______." Unless otherwise specified, this descent is made at the rate of 300 feet per minute.

(4) *Minimum altitude.*—(*a*) That altitude beyond which further descent on instruments is unsafe is known as the "minimum altitude." In every case where local conditions permit, this altitude is attained at the time the flight passes over the airport.

(*b*) Where it is practicable, range stations have been located a distance of 2 to 3 miles from the airport to facilitate this type of approach. At the bottom of the chart, this distance as well as the time required to traverse it at various approach speeds is shown in a convenient tabulated form.

(*c*) The rate of descent necessary to reach the specified minimum altitude in the allotted time will vary in some cases due to terrain, obstructions, distances, approach speed, etc. In only a few cases, however, will this rate exceed 500 feet per minute, and in most cases 300 feet per minute will be sufficient.

(5) *Missed approach.*—(*a*) Occasionally weather conditions are such that ground contact is not established at the minimum altitude. This condition is known as a "missed approach" and obviously necessitates immediate action for the continuance of safe instrument flight.

(*b*) Unless otherwise specified on the chart, a climb (500 feet per minute) is started immediately after the time necessary to reach the airport has elapsed. In most cases, this climb is continued to the initial approach altitude. During the climb a radio report to the ground station is to be made for further instructions.

SECTION III

INSTRUMENT LANDINGS AND RADIO COMPASS OPERATION

92. Instrument landings.—*a.* Instrument landing training should be conducted in accordance with the principles laid down in Air Corps T. O. 05–1–5. This training should be given only to pilots

who have qualified in the instrument flying test prescribed by Air Corps Circular 50-1. In this section the words "student" and "instructor" designate, respectively, any persons who take and who immediately supervise the course.

b. The following test is to be given: Three consecutive instrument landings of an airplane, while under the hood or otherwise suitably inclosed, will be made. These landings must be completed to the end of the roll of the airplane and will start at any altitude desired, but at the time the airplane is to be not less than 10 miles from the field where landing is to be made. Any assistance given by the safety pilot, from the time the hood is closed to the end of the roll after landing, will be considered as invalidating that particular flight.

c. Instrument landings are accomplished by executing with a high degree of precision certain maneuvers which are accurately combined in a standardized pattern regulated by the pilot's observation of radio signals. As seen in plain view, the pattern is fixed relative to terrain by three key points on the ground, two of which have radio compass locators and marker beacon projectors. The other has a runway localizer. The outer key point must be reached at a certain altitude measured by the pilot's altimeter. After reaching the outer key point, the airplane is held steadily in a power glide which will cause the inner point to be reached at a predetermined altitude and will result in an instrument landing on the runway. Failure to reach the inner key point at the prescribed altitude is a signal to the pilot to compensate for some previous error by use of the throttle or to go around again.

d. The instrument landing course is divided into subcourses in the manner indicated below:

(1) Study of Air Corps T.O. 05-1-5 and these instructions; good general knowledge, detailed familiarity with training routine and maneuvers.

(2) Practice of maneuvers in airplane, high accuracy in each.

(3) Practice of routine in instrument flying and landing ground trainer, time required 2½ to 10 hours; ability to make simulated landings so as to touch the runway within about 500 feet of the prescribed point; good control of altitude.

(4) In the ground trainer, the automatic recorder is used to show a record of each simulated landing.

(5) On command from the instructor, student opens throttle, holds gyro on zero, and causes instruments to hold maximum climb by use of controls. The airplane takes itself off.

(6) At a suitable altitude the student changes instruments to fast climb.

(7) Student initiates offset turn while still climbing, but goes to medium cruising when 800 feet altitude is reached. When the offset turn brings up the 90° mark on the gyro, the 400-cycle note on the inner station is turned in and the radio compass volume is increased to show about one-half scale deflection.

(8) The turn is stopped so as to center the radio compass and the pilot flies to the inner station at or above 1,000 feet altitude, reducing radio volume as desired. The minimum safe altitude to be used depends upon local terrain. During this time, he sets the turn indicator to 180°, cages the instrument, and tunes in the runway localizer.

(9) On receiving marker beacon flash from inner station, the student rapidly—

(*a*) Tunes in 800-cycle note on the outer station and increases volume.

(*b*) Centers radio compass.

(*c*) Releases gyro on 180° but flies by radio compass.

(10) On getting outer station marker beacon flash, being still about 1,000 feet altitude, check heading for 180° on gyro; student executes offset turn, controlling compass volume so as not to permit excessive deflection or annoying sound. Compass is centered and held centered. Altitude is slowly lost to 800 feet.

(11) Somewhere before reaching outer station again, the airplane is put in slow cruising.

(12) On receiving the outer station marker beacon flash, the following things are done as nearly simultaneously as possible:

(*a*) Tune in 400-cycle note on inner station, raise volume.

(*b*) Center compass, reset gyro if necessary.

(*c*) Put airplane in power glide at rate of descent predetermined for type plane being used.

(13) Maintain power glide and follow compass. Arrive over inner station at predetermined altitude for airplane being used. In event this altitude is reached before arriving at inner station, maintain level flight at predetermined altitude until arriving over inner station.

(14) At inner station flash, discontinue use of radio compass and use the runway localizer indicator and turn indicator (directional gyro). Maintain rate of descent.

(15) On contact with runway, close throttle, and after losing sufficient speed, apply brakes as required.

(16) When the routine is given in the ground trainer, the instructor marks the altitude every 100 feet on the chart at the proper places. The last mark (zero) represents the place of simulated landing in relation to the outline of the airdrome printed on the chart.

(17) The following explanation will indicate points to be concentrated on in practicing and executing the power glide:

(*a*) Control of artificial horizon gives greatest difficulty. This is because an almost invisible change in the pitch indication corresponds to a considerable raising or lowering of the ship's nose.

(*b*) Control of the radio compass is next most difficult; slow up the movement of the pointer as it approaches the center mark.

(*c*) When passing over the station and a change is made from slow cruise to power glide, the throttle may be completely retarded and then advanced to meet the rate of climb indicator at proper rate of descent.

93. Trainer radio compass operation.—With the student in the trainer and ready and the flight log moving across the map, turn on the radio compass switch on the small control box alongside the radio in the desk drawer.

a. Rotate the round, movable scale on top of the recorder until the 0 of this scale is in line with the spot representing the radio station on the map (fig. 55). Turn the radio compass (RC) volume control (on the small control box) about one-third on.

b. When the student turns the trainer until the inking wheel is moving directly toward the radio station on the map, the pointer in the cockpit will be centered on 0. The instructor must continue to keep the 0 of the movable scale (fig. 55) pointed toward the radio station.

c. As the recorder approaches the station, the instructor should gradually increase the radio compass volume. When the inking wheel gets close to the station, the instructor should move the round scale very slightly. As the student turns the trainer to center the left-right pointer again, the instructor should turn the scale slightly in the opposite direction. This causes the radio compass pointer to become difficult to manage and simulates the ultra sensitivity found near the station in actual flight. The instructor should cause this unruly tendency of the needle to become increasingly worse until the inking wheel passes over the station. At this point the rotating scale must be turned 180° in order to keep the 0 pointed toward the station. Turning the scale 180° also has the desired effect of causing the needle to give opposite indications. When the student again turns toward the station, the needle will be automatically corrected to give proper indications again.

94. Trainer automatic radio compass operation (for late type C–3 trainer).—*a.* The automatic radio compass fulfills the same function as the left-right radio compass, with the following important additions:

(1) The radio compass pointer indicates the radio bearing from the aircraft's nose to the station tuned in, instead of merely whether the station is to the left or right of the plane heading.

(2) Due to improved design, there is no 180° ambiguity of bearing possible such as was present in earlier type radio compasses.

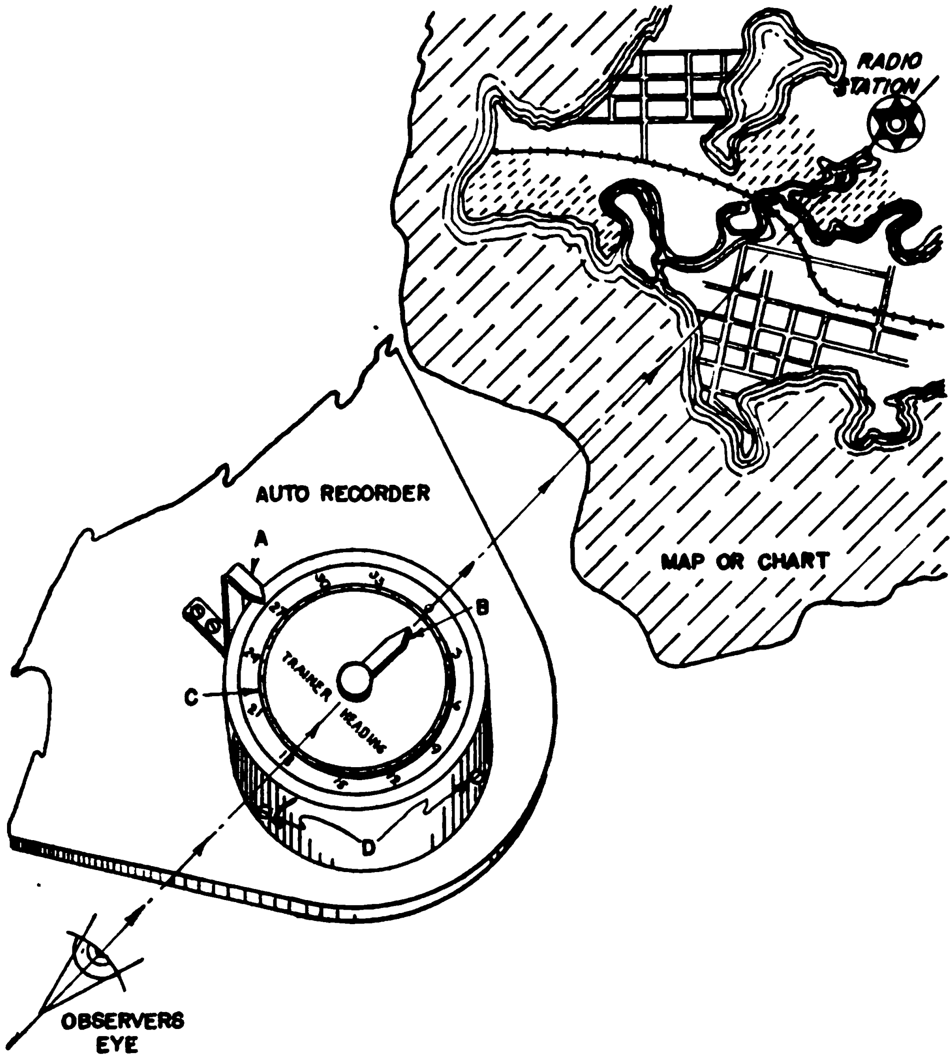

FIGURE 55.—Operation of radio compass control for radio compass problem.

(3) Radio bearings may be taken much more quickly than before.

b. To operate the automatic radio compass as a homing device, the student in the trainer notifies the instructor that he is tuning in the station selected, and turns on the switch in the cockpit marked "Automatic radio compass." The instructor then manipulates the control on the automatic recorder the same as for the left-right indicator. Homing is accomplished by turning the trainer until the compass indicator needle points to 0. As the recorder passes over the station, the recorder compass control should be quickly rotated 180°.

c. Instructions relative to the use of the automatic radio compass for obtaining radio bearings and establishing fixes are given in part one and in TM 1-205.

CHAPTER 3

WEATHER DATA; OPERATION AND PROGRESS RECORDS

95. Weather data.—*a.* Weather data should be injected into problems after the different systems of orientation have been taught and problems such as let-downs started.

b. Weather broadcasts should be given at points that will tend to confuse a pilot who does not have the situation well in hand. However, in the use of these broadcasts, be careful not to inject them into problems before the student has a fair understanding of orientation. Be sure that the simulated conditions correspond with conditions that actually can and do exist. For the ordinary problem, weather broadcasts may be put out at the proper times for the particular range being used, or special weather reports may be used, pertaining to winds aloft, made up to suit the situation.

c. Weather sequences prepared for the student's information in formulating a flight plan for cross country problems may be made up to present many different problems that will have to be taken into consideration. In addition to weather data furnished the student before the flight, changes may be effected and broadcast to require him to make changes during the problem. These changes may take the form of storm or icing conditions arising at point of destination or in the line of flight to destination. Instructions to change altitude, etc., should be broadcast to "other" ships in the vicinity. Here again the possibilities for different situations are limited only by the imagination of the desk operator. Make the weather conditions and any changes to them feasible. All meteorological data used in problems should be prepared and given in the manner and sequence as laid down in Air Corps Circular 105-2. Particular attention should be given to wind direction and velocity in giving weather reports, as any simulated wind must be allowed for in the wind drift mechanism if it is given on a weather broadcast.

96. Daily operation record (see form below).—A separate sheet is kept for each trainer being used. The name and grade of individuals flying the trainer, the type of work or problems that they

perform, their progress on the last exercise, and the time taken to perform them are entered in the proper columns. Total time of the individual's work is transcribed to the student's individual progress record while the total time of the trainer is entered on W. D., A. C. Form No. 47 at the end of the working day. This record is self-explanatory and should be faithfully followed and kept up. The usual procedure is to retain all forms for 6 months in a file that is easily accessible for reference. At the end of the 6 months the forms may be filed or destroyed at the discretion of the officer in charge.

LINK TRAINER DAILY OPERATION RECORD

Form ---------- Date ---------
Trainer type -------------- Organization --------------
Trainer No. -------------- Station ------------------

Name and grade	Time	Exercise	Grade	Remarks	Posted (initials)	Instructor

Total time ---------------- Instrument trainer officer ---------------

(Front)

INSTRUCTIONS

Each lesson conducted in the trainer will be entered, supplying the time in the trainer in minutes under "Time"; the number of the exercise or problem, as listed below, under "Exercise"; and A, B, or C, in accordance with the following, under "Grade":

A—If pilot remained within tolerance limits given in the instructor's guide for the particular exercise.
B—If student only occasionally slightly exceeded the specified limits.
C—If the pilot definitely needs more practice on the exercise in question as indicated by repeatedly exceeding tolerance limits.

Under "Remarks" note particular difficulties encountered by pilot. Under "Posted" insert instructor's initials when data have been posted to the individual progress record.

Each entry will be signed by the instructor.

Exercise number:

1----------- Familiarization.
2----------- Straight course.
3----------- Straight flight.

4	Standard rate turns.
5	Turns to predetermined headings.
6	Coordination of throttle and elevators.
7	Straight climbs and glides.
8	Climbing and gliding turns.
9	Climbing and gliding turns to predetermined altitudes and headings.
10	Repeat numbers 6, 7, 8, and 9 with rough air.
11	Repeat numbers 8 and 9 with rough air.
12	30°, 10°, 5°, and 2° turns to gyro headings.
13	Use of artificial horizon.
14	Emergency pull-up.
15	Stalls (without spinning).
16	Spins.
17	U-track.
Radio:	
R1	Signal familiarization.
R2	Beam interception and bracketing (mechanical).
R3	Beam interception and bracketing (advanced).
R4	90° system of orientation.
R5	Existing marker beacon uses.
R6	True fade-out system of orientation.
R7	Parallel system of orientation.
R8	Fade-out 90° combination of orientation.
R9	Parallel-perpendicular system of orientation.
R10	Lost on beam system of orientation.
R11	Multistation system of orientation.
R12	Unknown station system of orientation.
R13	Close-in procedure.
R14	Radio compass (homing).
R15	Radio compass (position finding).
R16	Let-down procedure and how to approach.
R17	Instrument landings.
R18	X country.

(Back)

97. Individual progress record.—The form following is as its name implies the student's record of progress in the course and is used as a record of problems performed by the individuals taking refresher time. The primary purpose is to furnish the instructor with a complete record of the student's progress and time used in the various phases of the instruction. One form will be kept for each student. The date he receives training will be entered in the column pertaining to the phase and date, also his progress on the last exercise. The form will be retained indefinitely in file by the instructor.

INDIVIDUAL PROGRESS RECORD

Form ----------
Name and grade ------------------------------
Organization -------------------- Station --------------------

Date	Time	Exercise	Grade	Trainer No.	Instructor	Remarks
--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------
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Total time ---------- Instrument time ----------
Radio time ---------- Instrument trainer officer -------------------------

98. Charts.—Air Corps instrument flying trainer charts will be obtained by requisition to the Assistant Chief, Air Service Command, Wright Field, Dayton, Ohio.

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BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION:

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(For explanation of symbols see FM 21–6.)

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